TRANSPORTATION RESEARCH
E-CIRCULAR

Number E-C013 January 2000

Presentations from the 12th Equipment Management Workshop

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Number E-C013, January 2000
ISSN 0097-8515

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August 2-5, 1998
Austin, Texas

Sponsored by Committee on Equipment Maintenance

TRANSPORTATION RESEARCH BOARD
National Research Council

In cooperation with
TEXAS DEPARTMENT OF TRANSPORTATION

Subscriber Category
IIIC maintenance

Transportation Research Board
National Research Council
2101 Constitution Avenue, NW
Washington, DC 20418

Foreword

Equipment managers in public and private organizations are responsible for all aspects of providing a diversified fleet of motorized equipment. Factors of concern to equipment managers include cost control, preventive maintenance, repair shop productivity, employee training and motivation, equipment replacement decisions, inventory control, commercial driver licenses, alternative fuels, environmental safety, privatization, electronically controlled diesel engines, and other related topics. Twelve Equipment Management Workshops have been conducted since 1976 to provide a continuing forum for the exchange of new ideas and developments in maintenance and management of equipment fleets.

The 12th Equipment Management Workshop was sponsored by the Transportation Research Board Committee on Equipment Maintenance in cooperation with the Texas Department of Transportation, in Austin, Texas, August 2–5, 1998. The proceedings of this Workshop are included in this Circular and are structured around the following topics:

- Improving Equipment Through Research
- Human Resource Management
- New Challenges—New Approaches
- 21st Century Fleet Management
- Alternative Fuels

Equipment research issues identified by workshop participants are being reviewed and expanded upon by members of the Committee on Equipment Maintenance for publication as research problem statements in future TRB Circulars. Planning is ongoing for the 13th Equipment Management Workshop scheduled for October 2000 in Sacramento, California.

Contents

From Concept to Reality: Advanced Technology and the Highway Maintenance Vehicle

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In 1995, departments of transportation (DOTs) in the snow belt states of Iowa, Michigan, and Minnesota began a multiphased project to define and develop the next-generation highway maintenance vehicle. Known for innovative highway maintenance management, operations, practices, and research, these states' DOTs formed the core research consortium, for which the Center for Transportation Research and Education (CTRE) at Iowa State University provided staff. The Federal Highway Administration (FHWA) and technology providers also participated. For each state, one prototype vehicle was developed, for which CTRE had established requirements during focus-group sessions. The incorporated technologies included

- PlowMaster and Global Positioning System (GPS), by Rockwell International;
- Hydrofire fuel injection system, by Fossen Manufacturing;
- Norsemeter friction meter, by Roadware Corporation;
- Fiber optic light system, by Innovative Warning System;
- Material application systems;
- Roadwatch warning system, by Sprague Controls, Inc.; and
- Search-Eye sensor system, by Global Sensor Systems, Inc.

The vehicles have been assembled and deployed to the respective states. Initial testing is completed; friction measuring devices have been compared; temperature sensors are calibrated; GPS readings are verified, and data has been transferred for analysis and reporting. A vehicle user manual was distributed. Test plans for winter roadway friction and pavement temperature were initiated.

Questionnaires were developed for equipment performance. The next phase of development will include a cellular-based data link; further evaluation of friction and temperature data; automated, onboard selection of chemicals and abrasives; and expanded technology applications.

INTRODUCTION

A universal challenge facing highway agencies and state departments of transportation (DOTs) is that of striving to increase productivity, quality, and environmental sensitivity while maintaining a constant or improved level of service on roads. These challenges are of major importance to three-quarters of the states' DOTs, who must face the perils of winter as they strive to provide uninterrupted mobility to the road user. Snow and ice control during winter storms includes highly complex tasks and long, stress-filled hours

both for equipment operators and for their supervisors. Continued cutbacks in DOT staffs dictate that one equipment operator must now be able to drive a snow-plow truck and manage all of its ancillary equipment. These staff reductions come at a time when road users require greater mobility and an increased level of service for winter driving. To address these issues, the concept highway maintenance vehicle project was undertaken by a consortium of three snowbelt states' DOTs —those of Iowa, Michigan, and Minnesota, all of whom have reputations for embracing innovation in highway maintenance management, operations, practices, and research. The Center for Transportation Research and Education (CTRE) at Iowa State University supplied the consortium with support staff, and FHWA joined the team and provided financial support, technical review, and opportunities to spread the word about the project. The key element of the project was the inclusion of private-sector partners who brought many assets, including staff with specialized expertise, business connections, manufacturing facilities, and the potential to participate in the funding and production of the vehicles.

Snow and ice control operations can benefit greatly from improvements in state-of-the-art onboard computer applications, enhanced safety systems, and improved equipment operator efficiency. Roadway surface temperatures may determine optimal timing and application rates of chemicals and abrasives. Automatic vehicle-location systems can track the progress of single vehicles and fleets. Advanced technologies that were integrated into the concept vehicles were

- PlowMaster and Global Positioning System (GPS), by Rockwell International;
- Hydrofire fuel injection system (power booster), by Fossen Manufacturing;
- Norsemeter friction meter (friction meter), by Roadware Corporation;
- Fiber optic light system, by Innovative Warning System;
- Material application systems;
- Roadwatch warning system (temperature sensors), by Sprague Controls, Inc.; and
- Search-Eye sensor system (back up sensors), by Global Sensor Systems, Inc.

Figure 1 illustrates the typical installation of technology for all three of the prototype vehicles.

Although many new technologies were installed on these three prototype vehicles, this paper will describe only the pavement temperature sensing devices that are used in conjunction with global positioning systems (GPS). The paper then presents the reactions of the equipment operators who were exposed to the advanced technologies during winter storm conditions and concludes by looking at what is in the future for these concept vehicles.

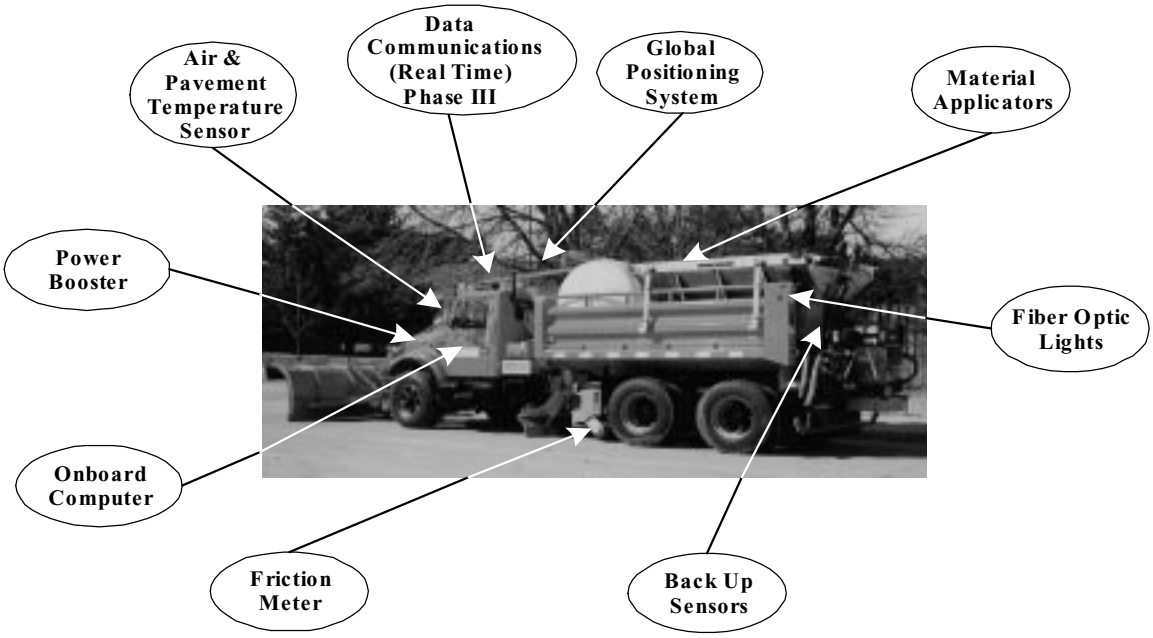

FIGURE 1 Typical technology installation.

Pavement Temperature

According to the Transportation Research Board, "Demands on highway agencies for fast and effective deicing sometimes result in indiscriminate salting. However, new developments in winter maintenance, including deicer application techniques (e.g., salt prewetting), plowing and spreading equipment, and weather and roadway monitoring (e.g., pavement sensors), are making these priorities less confusing" (*1*).

Pavement temperature is the controlling item in the effective treatment of highways during winter storms (*2*). Pavement temperature data may therefore be used to customize the rates of material application and the type of material utilized to match road conditions. CTRE research recommends selecting a salt application rate using a curve adapted from "Smart Salting: A Winter Maintenance Strategy," provided by the Vermont Agency of Transportation (VAT) (*3*). During the winter of 1993–1994, VAT conducted a study and coordinated pavement temperature information with winter highway maintenance activities, resulting in an anti-icing and deicing strategy. *Anti-icing* is the application of liquid chemicals and materials early in the storm or during plowing, to prevent the bonding of snow or ice to the road surface. By preventing bonding to the road surface, DOTs make the task of removing snow and ice much easier. Estimates in Iowa indicate a 50 to 60 percent reduction in the snow/ice removal effort when anti-icing procedures are utilized. *Deicing* is defined as the removal of snow/ice after the bond has formed. It is the procedure typically used in the past, before anti-icing was developed.

The Vermont study called for winter maintenance crews to do two things: first, determine pavement temperature before and during a storm; and second, determine salt application rates based on the relationship between pavement temperature, melting capacity of salt, and the thickness of ice or snow on the pavement.

TABLE 1 Vermont Study, Melting Capacity of Salt

Temperature (°F)	Pounds of Ice Melted Per Pound of Salt
30	46.3
25	14.4
20	8.6
15	6.3
10	4.9
5	4.1
0	3.7

The Vermont Study generated a graph correlating recommended salt application rates with pavement temperatures (see Figure 2). The Vermont study identified an economic salting range of 30° F down to 20° F. This is the temperature range within which salt is most effective in melting ice. The Iowa DOT estimates that 75 to 80 percent of Iowa's winter storms occur within this temperature range.

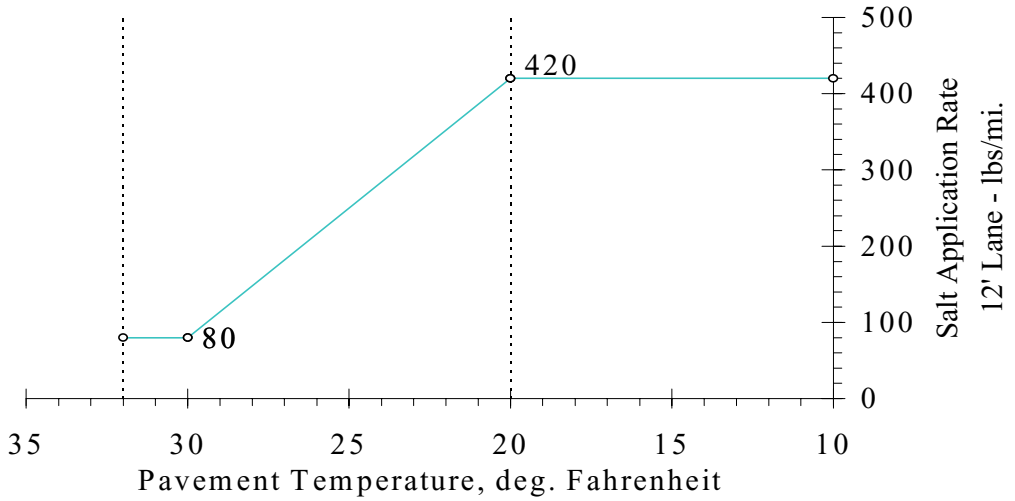

FIGURE 2 Vermont's recommended application rates.

All three prototype vehicles were equipped with the same pavement and air temperature sensors. The sensors have a road surface temperature range of -40° to 200°F and an air temperature range of -40° to 120° F. The sensors are accurate to within ±1 percent of full scale, or 1°F, whichever is greater. The recording response time is 1/10 second. The system is a passive infrared temperature indicator that uses infrared technology to read road surface energy and convert it to a temperature reading. The pavement sensor is mounted on the outside of the vehicle (typically on the driver's side mirror) and reads the pavement temperature directly below the sensor (see Figure 3).

FIGURE 3 Typical temperature sensor mounting.

To perform validity checks on temperature data, the following information was collected from the concept vehicles:

- Air temperature stamped with time and GPS location; and
- Pavement temperature stamped with time and GPS location.

The vehicles regularly recorded temperature data and stored these data on the Rockwell PlowMaster. The data were transferred to CTRE and converted to a d-Base format for analysis in Microsoft Excel. CTRE then generated charts of pavement and air temperature readings. The initial data are referenced by GPS heading, or by time at which the maintenance run began. Figure 4 shows a typical temperature plot versus time. Figure 5 illustrates the time reference after it has been converted to a milepost reference.

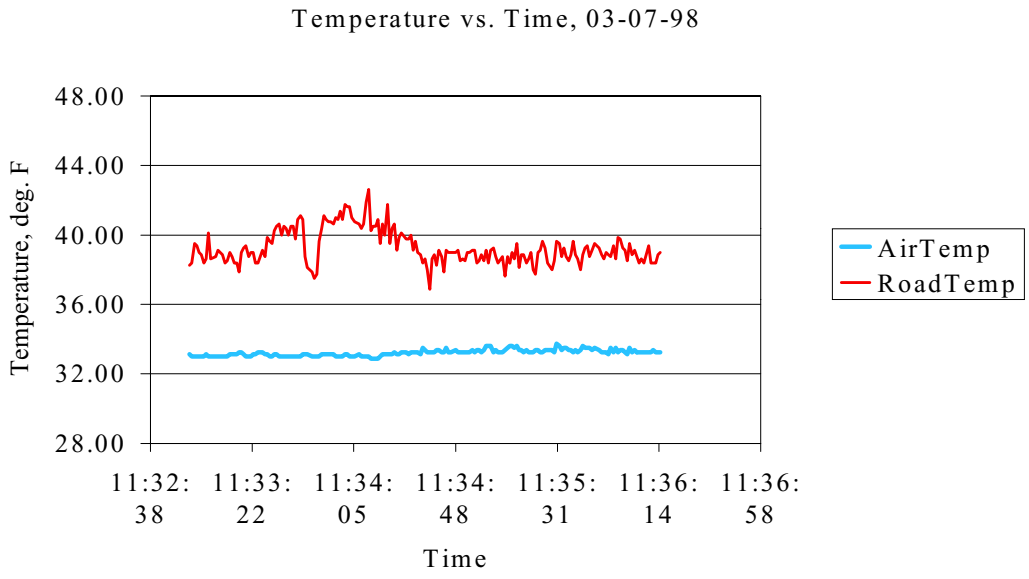

FIGURE 4 Temperature plot versus time.

GLOBAL POSITIONING SYSTEM (GPS)

GPS uses a constellation of 24 satellites that orbit the earth every 12 hours at an altitude of approximately 12,000 miles. The satellites are arranged into 6 circular orbits inclined 55 degrees with respect to the earth's equator. Their positions and orbits are always accurately known. Each satellite continuously transmits via a one-way radio communication channel the exact time. GPS antennas or receivers on the earth use triangulation, with at least three GPS satellites, to establish a position on the earth's surface. Each GPS receiver listens for the radio signal and calculates the elapsed time between radio signal transmission and reception. The GPS receiver then calculates the distance between the GPS satellite and receiver. More advanced GPS receivers can calculate vehicle speed using the difference in distance and elapsed time between two positions.

Since location data will be used for various functions of the concept vehicle, including pavement temperature plots, location of particularly icy spots on the road, and location of material applications, there is a need to compare the vehicle GPS coordinates with baseline coordinate data supplied by the DOT. The concept vehicle established GPS locations at mileposts along I-35 in Iowa, from milepost 88 to 102. This was accomplished by stopping the vehicle at each milepost marker and recording GPS coordinates. These coordinates were then compared to the officially published Iowa DOT milepost coordinates. CTRE corrected the concept vehicle coordinates to the Iowa DOT coordinates. This allowed the data coming from the concept vehicle to be reported by milepost. Figure 5 is an example plot of pavement temperature by milepost.

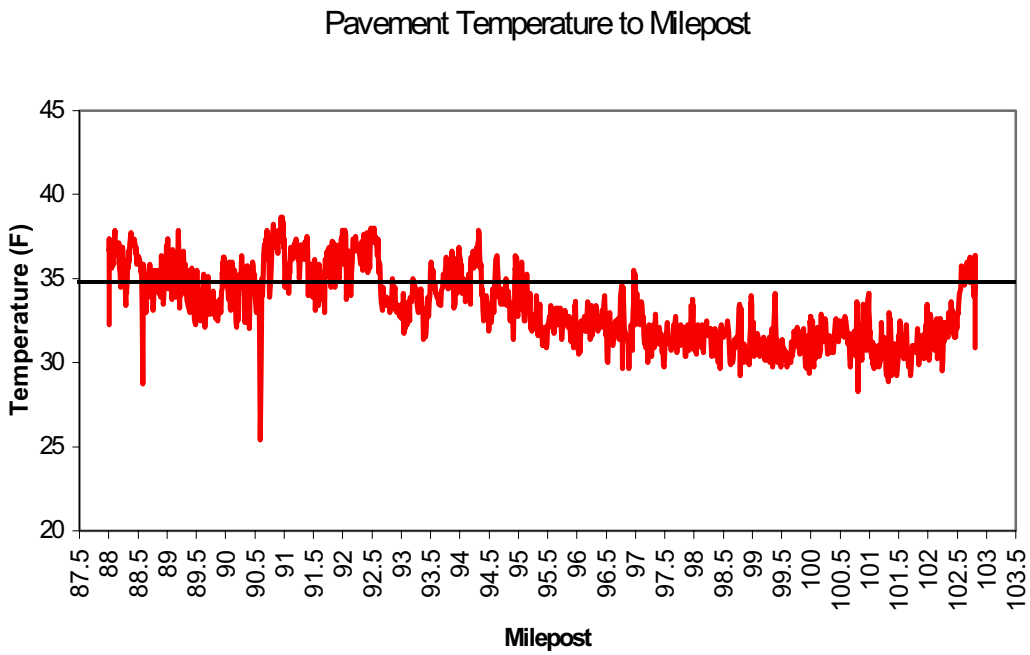

FIGURE 5 Temperature plot versus milepost.

This paper has discussed the value of pre-treatment during winter storms and has presented the most economical salt application rates. The paper has also described how the maintenance concept vehicle can record pavement temperatures and locate these temperatures by milepost. But what do the people who used this technology think? The following section reports the positive responses CTRE recorded from the equipment operators.

RESPONSES FROM EQUIPMENT OPERATORS

The winter of 1997–1998 was an important evaluation period for the prototype vehicles, including their performance and identification of malfunctions while performing normal winter maintenance assignments. Each of the three prototype vehicles maintained and treated roads in Iowa, Minnesota, and Michigan. The prototype vehicle operators and mechanics had firsthand experience with the vehicles' performance and played an active part in the research team, participating in meetings and conference calls throughout the project; subsequently, their feedback was key in the evaluation of vehicle performance.

Questionnaires and equipment performance log sheets were used to capture the reaction of the users to advanced technology applications. Interviews were conducted to determine if advanced technology has made the equipment operator's workload any easier or it if has added to the job. Following are the questions that were asked, each of which is followed by a summary of the responses given.

1. "What element of the new technology worked the best?" The operators appreciated the user-friendliness of the PlowMaster onboard computer. Equipment operators commented positively on the operation of the variable speed material applicators. With these applicators, the equipment operators can set a prescribed application rate at a given speed, and the material applicator compensates material application for changes in speed. One equipment operator termed the variable material applicator "user friendly." Although the material applicator is also found on some other winter maintenance trucks, the equipment operators appreciated the inclusion of the material applicator on the advanced technology vehicle.

2. "What element of the new technology worked the worst? Did this relatively poor performance have any negative impact on the operation of the other vehicle components?" Equipment operators faced continuous challenges with both the temperature sensors and the friction meter. At one point, the Iowa DOT reported the pavement temperature sensor as being off by as much as 30°F, prompting replacement of the sensor with a better-functioning one. The Iowa and Minnesota DOTs reported problems with broken belts on the friction meter, in addition to problems associated with corrosion of the friction meter's parts. When a particular piece of equipment malfunctioned or failed, it was usually rendered out of service until the vehicle returned to its garage. However, even when the equipment malfunctioned, the drivers reported that they were still able to operate the truck at or above the same level of service with which they operated conventional snow plows. This fact is important and shows the advanced technology vehicle can still complete the basic assignment even when the technology is temporarily not available.

3. "Was the PlowMaster display easy to read while you were driving?" The PlowMaster screens required some learning but the operators admitted that they experienced similar situations whenever they received a new piece of equipment. Equipment operators reported that the screen dimness and brightness feature of the Rockwell PlowMaster display was relatively easy to read. During the day the operators would brighten the screen, and during the evening the operators would dim the screen. The only reported problem (from the Minnesota DOT) with reading the PlowMaster display occurred during direct sunlight. The screens were designed to be logical and easy to follow. Equipment operators reported being able to quickly call up information reported by the PlowMaster computer.

4. "How did the added technology on the prototype vehicle affect your comfort and attention to the road, as compared with conventional maintenance trucks? Was the added technology a detriment or enhancement to the attention you could give the road?" The equipment operators reported that the advanced technology helped them focus more of their attention on the road, especially when the equipment was functioning properly. The technology took tasks out of the hands of the equipment operators and allowed them to focus their attention where it was needed. Of key importance was the statement made by equipment operators at all three state DOTs concerning the periods when the equipment malfunctioned. The operators reported that during these periods they were able to operate the truck without a loss in productivity when compared to their experience with the operation of conventional DOT snow plows. This suggests that the prototype trucks can function as adequately as would conventional snow plows if there is a failure in the advanced technologies. After the initial time used to become familiar with the new technology, equipment operators were able to use the technology with relative ease, and with greater efficiency than they used conventional snow plows.

5. "Any other problems you had with the truck while driving it?" Equipment operators from Iowa reported the present location of the material applicator requires them to stop the vehicle whenever they change the material applicator's settings.

6. "What suggestions for improvement do you have?" Iowa equipment operators suggested changing the placement of the material applicator controls in order to allow the operator to adjust the settings while the truck was moving.

All of the responses to these questions were positive and supportive. Figure 6 illustrates the responses CTRE received. The responses also indicate that the equipment operators are looking into the future and presenting input for modifications and refinements to be made.

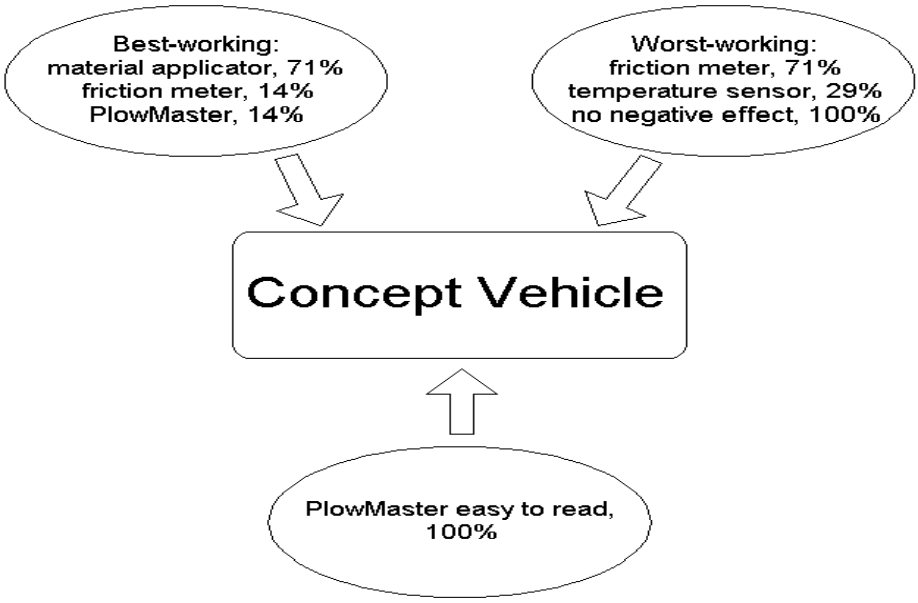

FIGURE 6 Equipment operators' responses.

REQUIREMENTS FOR NEXT-GENERATION PROTOTYPE VEHICLES

After the first prototype vehicles completed their assignments for the winter of 1997 to 1998, the experiences were reviewed and appropriate modifications and changes were detailed for the next-generation prototype vehicle. A development schedule will be established for the modifications required and for the incorporation of new technologies. The following technologies have been identified for integration with the concept vehicle:

Differential GPS (DGPS)

The 1997–1998 prototype vehicles used conventional GPS, which has potential location errors of 100–300 feet. DGPS provides greater location accuracy, with errors of 5 feet or less. DGPS also provides higher location accuracy, which is important when identifying specific route locations requiring specialized treatment. Rockwell International, the provider of the conventional GPS units for the prototype maintenance vehicles, will retrofit the existing prototype vehicles with DGPS receivers. The DGPS applications on the prototype vehicles were adapted from agricultural applications. DGPS also uses United States Coast Guard beacons; because of this, the DOTs would not be responsible for maintaining the DGPS beacons.

Collision Avoidance System

Weather and driving conditions during winter maintenance activities are often less than ideal. Heavy snow, blowing snow, and fog sometimes reduce visibility to near zero. Stopped or stalled cars along the road present a danger for other drivers, including drivers of the maintenance vehicles. Sometimes snow-plow-car accidents occur. Such collisions are costly for everyone. In addition to collisions involving vehicles, the collision

avoidance system could be set up to help the maintenance vehicle avoid guardrails and bridge wing posts. DGPS could be used to establish and log a guardrail and bridge inventory, which could then be consulted when visibility is poor. Consequently, a collision avoidance system on the maintenance vehicles is beneficial.

Cellular Phone Communications Link

Presently, pavement and air temperature data and friction data are recorded by the PlowMaster on a PCMCIA card. The card is then removed from the PlowMaster for downloading of data. Although this is a good way to record and transfer data, it is desirable to transmit real-time information from the prototype vehicle to base stations (garages). Road and air temperature, friction values, and DGPS location are valuable for decision making at the base station. A feasibility evaluation of using cellular phone communications for transmitting data from the vehicle to the base station is being completed.

The major expense for cellular communications is in the connect (20–40 seconds) and disconnect (20 seconds) time. This fact has led the research team to look at other communication links, namely the radio infrastructure at each DOT.

Radio Communications Link

Radio communications are less expensive than cellular phone communications. Each prototype truck would be equipped with a radio transmitter that uses the existing DOT radio infrastructure to send data to the vehicle's base location.

Mapping Packages

Data collected from the prototype vehicle are initially displayed in tabular or spreadsheet format. A better method of displaying data is in graphic, or map, format. A point-and-click interface is envisioned, one that would allow the user to click on a point on the map and obtain temperature, friction, and treatment material information for that point on the road.

CONCLUSION

The acceptance of new technology applications by equipment operators and others whose jobs are related to the highway maintenance vehicle is critical to its success. Because they had been involved in the development of requirements for, as well as throughout the development and implementation of the technologies themselves, the equipment operators embraced the new technologies. As a result of the operators' cooperation and willingness to make the technologies a productive tool, the concept vehicle can measure pavement temperature, locate the vehicle position by GPS, and provide reports by milepost.

ACKNOWLEDGEMENTS

The author wishes to thank the people at the Iowa, Michigan, and Minnesota DOTs who worked so hard to make this project a success. Without their full support, the concept maintenance vehicle project would not be as successful as it is today. The private sector partners were invaluable for supplying the technologies, assembling them on the vehicles, and then providing support during the initial stages of the project.

REFERENCES

1. Transportation Research Board. Highway Deicing, Comparing Salt and Calcium Magnesium Acetate. *Special Report #235.* Transportation Research Board, National Research Council, Washington, D.C., 1991.
2. Boselly, S. Edward, III. Benefit-Cost Assessment of the Utility of Road Weather Information Systems for Snow and Ice Control. *Transportation Research Record No. 1352*, Transportation Research Board, National Research Council, Washington, D.C., 1992.
3. Vermont Agency of Transportation. *Smart Salting: A Winter Maintenance Strategy.* Maintenance Division, Vermont Agency of Transportation, 1995.

AASHTO's Winter Maintenance Program: A Proactive Approach to International Technology Transfer

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Each winter, state and local governmental transportation agencies across the United States are commonly faced with the need to control snow and ice on their highways and roads. Conditions such as occurred in the winter of 1993–1994 in east central United States; 1995–1996 in Pennsylvania, New York, Virginia, and Washington, D.C.; 1996–1997 in North and South Dakota and Minnesota; and 1997–1998 in the Midwestern States raise severe safety hazards for those who are traveling and have a major negative economic impact on the area. Even though public transportation agencies have developed and applied an array of practices and techniques for snow and ice control to minimize winter hazards and make highways, roads, and streets safer for travel, their customers—the traveling public—desires more. Therefore, these agencies are continually looking for better ways to address snow and ice problems.

One such effort to seek better ways of snow and ice control was a 1994 International Winter Maintenance Technology Scanning Tour sponsored by the American Association of State Highway and Transportation Officials (AASHTO), through the National Cooperative Highway Research Program (NCHRP) and the Federal Highway Administration's (FHWA's) International Outreach Program. A group of state and local government winter maintenance experts, together with a representative from the FHWA, was constituted as a Scanning Team and visited winter maintenance road officials in Japan and Europe. The Scanning Team found many equipment technologies and winter maintenance systems improvements during the tour that were not used in the United States, but were believed to be of potential benefit to Americans.

The Scanning Team developed a proposal for a Winter Maintenance Program and presented those findings to the AASHTO Subcommittee on Maintenance and the Standing Committee on Highways. The Winter Maintenance Program was subsequently presented to the AASHTO Board of Directors and adopted at its November 1994 annual meeting. The Program is designed to have a collaborative relationship with AASHTO and Transportation Research Board (TRB) Committees, such as the Committee on Maintenance Equipment, the sponsor of this 12th Equipment Management Workshop.

This paper describes details of that program and the progress that has been made toward implementation.

INTRODUCTION

North Americans spend $20 billion annually on snow and ice control (*1*). Still, nearly every winter, major blizzards and ice storms occur in various areas of the United States, crippling transportation, producing major negative economic impacts, and inflicting severe safety hazards on travelers. While governmental transportation agencies have developed a variety of improved practices and techniques for better snow and ice control

to minimize winter hazards and make travel safer, these agencies are continually seeking better ways to handle snow and ice problems. In an effort to find better ways of improving snow and ice control operations, an International Winter Maintenance Technology Scanning Tour was conducted in 1994. The Scanning Team was comprised of a group of winter maintenance experts from state and local government, together with a representative from the FHWA. The Scanning Team met with winter maintenance road officials in Japan and Europe.

During the Scanning Tour, many equipment technologies, procedures and winter maintenance systems were observed that were not being used in the United States, but which the Scanning Team believed would be of significant benefit to Americans. The Scanning Team developed a proposal for a Winter Maintenance Program which would conduct rigorous operational acceptance testing and evaluation of international and domestic winter maintenance technologies to determine their value for snow and ice control in the United States, and to support introduction of those acceptable technologies (*2*).

The Scanning Team presented its findings and the proposed Winter Maintenance Program to the AASHTO Subcommittee on Maintenance at its summer meeting in July 1994, and to the AASHTO Standing Committee on Highways at its annual meeting in November 1994. On November 13, 1994, the AASHTO Board of Directors approved the establishment of the Winter Maintenance Program. The remainder of this paper details the content of the Winter Maintenance Program, the establishment of the Snow and Ice Cooperative Program (SICOP), and the progress that has been made during the past 2.5 years.

WINTER MAINTENANCE PROGRAM

The Scanning Team was impressed with the systems concept that Japanese and European officials used for snow and ice control. The systems concept addressed the vehicle, the driver, and the equipment, as well as the practices for managing roadway and bridge snow and ice control. The AASHTO Board of Directors concurred with the systems concept when it approved its Administrative Resolution AR-3-94 (*3*), which supported

> *…the establishment of a project under the National Cooperative Highway Research Program (NCHRP) to develop a comprehensive guide for establishing a systems approach to snow and ice control that addresses the vehicle, the driver, and equipment and practices for managing roadway and bridge snow and ice, for use by Member Departments and local governments to provide them guidance suitable for their geographic and weather conditions. The goals for such a system concept should be to: sustain or improve levels of winter maintenance service with significant cost/benefit improvements; provide an enhanced level of environmental protection; and increase the safety of driving under winter conditions.*

The Administrative Resolution continues:

> *In order to experiment with snow and ice technology and systems not now in use in this nation, to determine their suitability to the United States and to help introduce the use of those with the most promise, the AASHTO Board of Directors endorses the concept of establishing a voluntary AASHTO Snow and Ice Pooled Fund Cooperative Program, under which testing by AASHTO Member Departments volunteering to sponsor and conduct tests can be supported financially with public sector funds voluntarily.*

The resolution requested that an AASHTO standing Winter Maintenance Policy Coordinating Committee (WMPCC) consisting of representatives from AASHTO member states, the National Association of County Engineers (NACE), and the American Public Works Association (APWA) be established to monitor and guide the development and implementation of the Winter Maintenance Program. The WMPCC was subsequently appointed by the AASHTO President and the first phase of the Program started.

Development of the Comprehensive Winter Maintenance Guide

This first phase utilized funding under NCHRP Project 20-7, Task 71, to establish a broadly based NCHRP snow and ice control panel and conduct a national workshop to guide the development of the comprehensive winter maintenance guide (*4*). The workshop was held in Washington, D.C. A work program was developed and an extensive outline was produced for the comprehensive guide. A contractor for NCHRP Project 20-7, Task 83, completed development of the guide (*4*). A draft of the guide was ready for review by the AASHTO Subcommittee on Maintenance at its summer meeting in July 1998.

Establishment of the Snow and Ice Cooperative Fund Program

The second phase was launched at the AASHTO annual meeting in October 1996 when the Standing Committee on Highways adopted the following motion:

> *Resolved that based on the favorable returns of a September 4, 1996, ballot of the Member Departments to determine interest in establishing and funding an AASHTO Snow and Ice Pooled Funded Cooperative Program (SICOP), the AASHTO staff be authorized and directed to proceed with implementation of the SICOP, including invoicing the Member Departments agreeing to support start-up costs, in accord with the overall direction provided by AR-3-94.*

Thirty-four states, NACE, and APWA each contributed $4,000 to the start-up phase and are actively participating in SICOP.

In December 1996, the WMPCC met to determine what was required to get SICOP up and running. The Scanning Team had originally recommended 11 SICOP project areas. A survey of SICOP participants conducted in 1996 provided information on what was currently being done and not being done in these 11 project areas. A literature search was completed showing planned, ongoing, and completed research, as well as articles published nationally and internationally on snow and ice control. The WMPCC reviewed these materials, determined three additional topics that needed to be added to the project list, and developed an agenda for a SICOP workshop held in Minneapolis, Minnesota, in April 1997. At this workshop, participants reviewed published and ongoing snow and ice control research and evaluation projects, identified gaps between what was needed and what existed or was ongoing, and developed project problem statements for additional research or evaluation projects to fill voids. More than 100 snow and ice control practitioners, equipment specialists, and researchers participated in the 2-day workshop. Breakout sessions led by experienced facilitators provided for in-depth discussions of the SICOP topics. Workshop proceedings were assembled and published in the summer of 1997.

In October 1997, the WMPCC met at AASHTO Headquarters, evaluated the results of the workshop, and determined the next steps for SICOP. The Committee members developed preliminary statements of work and selected the following ten topics as being of the highest priority (listed in priority order):

1. *Anti-icing training for state, county, and municipal highway operations*. The objective is to develop and deliver a comprehensive training program on anti-icing strategy, materials, and procedures for personnel in state and local governments.
2. *Road and weather information system (RWIS) training*. The objective is to develop and deliver a comprehensive training program on the use of RWIS for decision makers regarding winter snow and ice control operations on roadways. Training would utilize realistic scenario-based exercises. Existing mindsets need to be changed and knowledge relative to weather-impacted activities must be transformed into actions based on data and forecasts produced as part of RWIS.
3. *Develop and validate test methods for anti-icing and deicing materials*. The objective is to recognize that since the completion of the Strategic Highway Research Program (SHRP) and FHWA post-SHRP work, some new or modified materials, or both, have been developed and offered for use. With participation of material producers and end users, determine what materials are used in anti-icing and deicing operations and determine the significant characteristics of the materials used.
4. *Urban snow and ice control, best method practices*. In cooperation with NACE and APWA, the objective is to identify special issues impacting winter weather operations in urban environments, and respond with guidance on best management practices and training to achieve wide application of such practices.
5. *Investigate the use and application of Global Positioning System (GPS) equipment and technology in winter maintenance operations*. The objective is to determine the applicability of GPS equipment and technology for improving the efficiency and effectiveness of snow and ice control activities. GPS equipment is available now and is being used in fleet management. Can it be used effectively to monitor snow and ice control maintenance operations?

6. *The measurement of friction on highway pavements during winter activities*. The objective is to identify equipment and determine methods for the measuring and evaluating of friction on pavements during snow and ice control operations. Determine winter friction values that should be maintained at different levels of service in the United States. Winter pavement friction technology is already in use in Japan (*5*) to set safe speed limits on expressways and in European countries (*6*) to establish contract levels of service for winter snow and ice control.
7. *Winter maintenance publication information and public relations*. The objective is to form a Winter Maintenance Public Information Task Force under WMPCC charged with identifying and recommending activities to improve communication about winter travel conditions and winter maintenance strategies. This would include the development and promulgation of adequate standards of uniformity for data collection and information dissemination.
8. *Driver education and training*. The objective is to develop a winter driving techniques module that could be incorporated into driver education classes nationwide. Review how government agencies develop and deliver information for the public on winter travel tips, techniques, and guidance. Develop a best practices guide.
9. *More Technology Transfer (T^2) Center or Local Transportation Assistance Program (LTAP) resources on anti-icing for local governments*. The objective is to make more information on "best" snow and ice control practices available to counties and municipalities for both their urban and rural snow and ice control responsibilities, especially in support of anti-icing implementation and training.
10. *Creation of a task force under WMPCC to investigate and evaluate opportunities for using computerized controls and onboard interactive display devices in snow and ice control*. The objective is to investigate and evaluate opportunities for using computerized controls and onboard interactive display devices for partially or fully automated snow and ice control equipment functions.

Proposed 1998 SICOP Work Program and Implementation Plan

The WMPCC agreed to concentrate SICOP efforts on the above listed ten projects. These projects fit into four broad categories: *Training* (Problems #1, #2, #4, #8, and #9); *Materials applications and specifications* (Problem #3); *Technological advancements* (Problems #5, #6, and #10); and *Public relations/communications* (Problem #7). Expert task groups are now being formed in each of the four categories to provide guidance and oversight. As soon as the expert task groups are assembled, they will develop matrices showing who is currently conducting research, testing and evaluation, technology transfer, and implementation activities in each area, with what resources, and at what cost. They also will identify appropriate AASHTO committees with which to liaison on each of the above projects and establish a collaborative relationship. This collaborative relationship will likely include Transportation Research Board's Committee A3C08 (Maintenance Equipment), the committee sponsoring this 12th Equipment Management Workshop, A3C09 (Winter Maintenance), and A3C03 (Maintenance and Operations Personnel); and AASHTO's Subcommittee on Maintenance, specifically the Task Force on Equipment and the Task Force on Safety and Winter Operations.

The WMPCC and expert task groups will then establish a work program and budget for each of the ten projects and locate commitments for funding them by

- Soliciting the AASHTO member departments, cities, and counties, and the FHWA, to determine their interest in supporting and funding the projects;
- Approaching private sector and foundation entities, to determine their interest and the availability of funding; and,
- Considering the use of NCHRP as a resource for conducting research projects.

As soon as funding commitments are adequate, WMPCC would obtain concurrence from the AASHTO Standing Committee on Highways to proceed with implementation of the work program. Status reports will be made semiannually to the Standing Committee on Highways. The first status report was presented at the AASHTO mid-year meeting, April 18, 1998. The Minnesota Department of Transportation is supporting a loan staff to work full time with AASHTO's Program Director for Engineering to administer the SICOP program.

Second Winter Technology Scanning Tour

A second winter technology scanning tour was conducted in 1998. The first tour, conducted in 1994, concentrated its scanning efforts to winter maintenance operations in Japan, Germany, and Austria, while the second tour scanned Switzerland, France, Norway, and Sweden. Most of the findings made in the 1994 tour were being utilized in the four countries visited in 1998. One of the major findings on the 1998 tour was the vast improvement in cab ergonomics on snow plowing trucks. As they had in the past, the Europeans were leading the way in modern cab design—with wraparound windshields, contoured dash panels and operator seats, and fingertip "joystick" plow controllers. Visibility from the operator's seat was greatly improved over that found in U.S.-designed trucks. There was also improvement in composite material snowplow blades. In 1994 the discovery had been the use of rubber squeegee blades for slush and water removal behind the steel plow, but now the composite blade could do the job of two blades. These new discoveries will be utilized in the SICOP program.

Other Winter Maintenance Programs

Following publication of the results and recommendations of the 1994 scanning tour (*2*), several smaller Winter Maintenance Program projects were developed and field tested; some examples are snow plow shields to improve snow plow truck operators' visibility and the rear-mounted wind scoop to improve snow plow truck conspicuity (*5*). Projects of larger scope, such as the Maintenance Concept Vehicle being developed by the three-state consortium of Iowa, Michigan, and Minnesota, have technology advancements that were discovered on the 1994 international scanning tour (*7*). All of these projects will be integrated into the SICOP program. The utilization of friction measurements will require national testing and evaluation, not to mention consensus, before it will be adopted by all snowbelt states and integrated into the Intelligent Transportation System.

SUMMARY

The increasing need and desire for safe, year-round mobility for the highway user places great responsibilities on the shoulders of transportation providers. While governmental transportation agencies have developed and implemented a variety of improved practices and techniques for better snow and ice control to alleviate winter hazards and make travel safer and more reliable, progress has been painfully slow. The Strategic Highway Research Program (SHRP) showed that other material application and snow removal techniques could, at least in theory, improve efficiency and effectiveness of winter operations. International winter maintenance technology scanning tours discovered that some of the SHRP research has been implemented with great success elsewhere in the world. AASHTO's Winter Maintenance Program is designed to stay current with what is the latest cutting edge equipment, materials, and methods technology for snow and ice control. SICOP focuses on testing, evaluating, and implementing that technology.

Since SICOP operates as a self-supporting AASHTO technical service program and relies on voluntary contributions from its member departments (NACE and APWA), the next major implementation effort will be to solicit funds and interest in supporting each project. With a full-time loan staff on board, it is envisioned the program will pick up momentum and some of the high priority projects will be under way by fall 1998.

The SICOP program is flexible enough that future technologies—such as those being assembled in the Maintenance Concept Vehicle and those discovered during the winter 1998 scanning tour—and future tours can be folded into the ongoing program.

REFERENCES

1. Kuemmel, David E., "Managing Roadway Snow and Ice Control Operations," *NCHRP Synthesis of Highway Practice 207*, Transportation Research Board, National Research Council, Washington, D.C., 1994, p. 1.
2. Decker, Rand, and Amir N. Hanna, "Winter Maintenance Technology and Practices—Learning from Abroad," *NCHRP Research Results Digest Number 204*, Transportation Research Board, National Research Council, Washington, D.C., January 1995.
3. *Establishment of Winter Maintenance Program*, Administrative Resolution AR-3-94, American Association of State Highway and Transportation Officials, Washington, D.C., November 13, 1994.
4. *National Cooperative Highway Research Program Progress Report 87*, Transportation Research Board, National Academy Press, Washington, D.C., 1997, pp. 282 and 286.
5. Smithson, L. D., "Americans Can Learn a Lot From European, Japanese Snowfighters," *Roads and Bridges*, Volume 33, Number 6, June 1995, pp. 30–32.
6. Perchanok, Max S., "Friction Based Quality Assurance Measures for Snow Clearing Operations," *Technical Report Volume 1, Xth PIARC International Winter Road Congress, Luleå, Sweden*, PIARC–World Road Association, Nord, France, 1998, pp. 199–208.
7. Smithson, L. D., "DOTs Push For Better Snow Control Vehicles," *Better Roads*, Volume 67, Number 6, June 1997, pp. 27–29.

Texas DOT Vehicle Fleet Warning Light Policy Research

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This paper presents an overview and preliminary results of current research being conducted by the Texas Transportation Institute (TTI) and the Texas Department of Transportation (TxDOT) to improve the latter's vehicle fleet warning light policy and procedures. Although the need for vehicle warning lights is well understood and mandated by law, the large number of design options available (types of lights, lens colors, mounting positions, and combinations thereof) to transportation agencies such as TxDOT makes establishment and maintenance of a consistent policy regarding vehicle warning lights difficult. Also, there is considerable and growing pressure to incorporate into maintenance and service vehicles lighting technologies that are visually similar to those implemented on police and other emergency vehicles (e.g., light bars or blue flashers).

Research conducted by TTI and TxDOT and presented in this paper includes the results of a national survey of vehicle warning light policies by state DOTs, a review of human factors and driver behavior research that has influenced warning light policies over the years, and studies of motorist comprehension and driving responses to different warning light configurations. Specifically, studies are being conducted in several cities statewide to determine the types of vehicles (police, fire, maintenance, tow services, and so forth) and the relative degree of concern or caution drivers commonly associate with different vehicle warning light color configurations. Field studies are also being performed to determine the differences in driver behavior (measured in terms of speed, lane choice and lane changing, and brake application) as drivers approach a vehicle parked on the shoulder with one of three different vehicle warning light configurations displayed (red-blue-yellow configuration, blue-yellow configuration, or all-yellow configuration). These objective data on motorists' perceptions and responses will help TxDOT policymakers to ensure that the vehicle warning light systems utilized fulfill a real need, that they are credible to the public, and that they elicit correct and consistent reactions by drivers.

INTRODUCTION

The Texas Department of Transportation (TxDOT) has the responsibility of establishing policy and rules regarding the provision and utilization of special flashing warning lights on all vehicles and equipment used for highway construction and maintenance operations in the state (*1*). This policy specifies such items as the types of vehicles that require special warning lights, appropriate mounting locations for the lights, situations where the lights are to be used, and basic features of the lights themselves (color, size, type, and

performance characteristics).

Maintaining this vehicle warning light policy is an ongoing challenge for the Department. Warning light technology continues to improve, and new devices are constantly being introduced into the marketplace. It has become increasingly difficult for the Department to differentiate between true improvements in warning light technology and vendor "hype" for a particular product. Some degree of warning light technology standardization is necessary within TxDOT, both to achieve economies of scale during purchasing and to promote driver understanding and anticipation of lights to be seen on TxDOT (and other construction or maintenance) vehicles. However, such standardization must not impede real opportunities to improve worker and motorist safety. Because of these and other concerns, TxDOT has sponsored research by the Texas Transportation Institute (TTI) to examine its current vehicle warning light policy and to determine recommendations for improvement. This paper presents some of the significant findings that have arisen from that research effort.

BACKGROUND

Flashing vehicle warning lights have two primary functions. The first is to attract the attention of nearby drivers and pedestrians, in order to alert them to the situation they are approaching, or to one that is approaching them. The second function is to provide those drivers and pedestrians with information about the situation so that they can take whatever action is needed and appropriate. With respect to the first function, a significant amount of research has gone into the understanding of human visual perception and detection of flashing warning lights. This research has shown that the detection (or conspicuity) of a light is predominantly dependent on the effective intensity of its flash, with generally higher flash intensities associated with increased conspicuity (*2*). However, a flash too intense can have a deleterious effect by temporarily blinding an individual, particularly at night.

Other characteristics of a light, such as the flash rate, on-off cycle, flash pulse shape, and flash duration, also influence human detection capabilities (*2*). With respect to flash pulse shape and duration, a significant difference exists between rotating or flashed incandescent lights, which have a rather long duty cycle, and gaseous-discharge lamps (strobe lights), which emit an extremely intense light over a very small time duration (generally around 0.001 second). Whereas strobe lights tend to be more efficient at converting electricity into light than are incandescent lights (*3*), evidence suggests that the extremely short duration of the flash hinders some drivers' ability to estimate distance from and movement toward the light. To counter this effect, strobe manufacturers have developed multiple-flash units, spreading the total flash intensity out over two or more closely-spaced flashes. Originally used in roadway applications beginning in 1968, strobe lights have become an integral part of warning light systems used for many emergency warning, highway construction, and highway maintenance vehicles. In order to benefit from the strong points of both types of lighting technologies, departments of transportation (DOTs) make use of combinations of incandescent and strobe lights.

Likewise, the color of the light also has some effect on its conspicuity. In daylight conditions, red lights have been shown to be more conspicuous than are blue lights, whereas the opposite is true under nighttime conditions. Interestingly, the conspicuity of

yellow lights generally falls between that of blue and red lights in both daytime and nighttime viewing conditions (*4*).

In addition to the above characteristics, the number of flashing lights on a vehicle also affects the likelihood of detection and perception of that vehicle by a driver. Theoretically, each light added to a vehicle increases the probability that it will be seen under a given viewing condition. Of course, space limits the number of lights that can be added to a given vehicle. Perhaps more importantly, the additional conspicuity (detection potential) gained through the addition of more lights, different lighting types, or mounting of configurations may reach a practical maximum. For example, does the ability to detect a vehicle from 1 mile away offer substantial safety advantage over the ability to detect it from .5-mile away? Similarly, does a reduction in detection time from 0.25 to 0.23 seconds (these are purely hypothetical values) help improve safety to a significant degree? The real question is whether an improvement in safety justifies the additional expense and complexity associated with installing and operating a more complex lighting system.

Studies conducted in the late 1980s lent some insight into the practical differences that can be expected from certain alternative warning light systems for maintenance (service) and construction vehicles (*5*). Researchers conducted some experiments to determine motorists' ability to estimate speeds of maintenance vehicles outfitted with each of the alternative systems, as well as their ability to judge the rates at which they were closing in on each of those vehicles. Other experiments examined the effects of lighting systems on driver lane-changing behavior relative to the location of the maintenance vehicle. The study examined several factors related to light design (flash rate, flash intensity, flash mounting location, flash type) but limited the evaluation of light color to yellow (or amber). This was done because yellow is used almost exclusively for maintenance vehicle applications throughout the United States, and because many states restrict the use of other colors to authorized emergency vehicles only.

Although a limited number of alternatives were examined, the results did show that factors such as flash rates (between 60 and 100 cycles per minute), flash intensities, and flash mounting locations did not have measurable effect on the performance measures examined in the study. Combining different types of flash technologies (e.g., four-way flashers with a flashing warning light, combinations of rotating and flashing warning lights together on a single vehicle) did result in slightly improved responses. Strobe lights, although superior for conspicuity purposes, did not yield good judgments about vehicle speed or closure rates in comparison to those achieved with incandescent flashing lights. This was true for both the single- and the double-flash strobes tested.

Another interesting finding was that the most effective vehicle warning light system differed depending on whether the study was performed at a short-term stationary lane closure or as part of a continuously moving operation. For moving operations, an all-yellow light bar system (with rotating elements) was effective. However, this system did not work as well in a stationary lane closure environment. The researchers hypothesized that some motorists incorrectly associated the light bar with a moving operation (such as tow truck), and so did not change lanes until they were almost on top of the work zone. The rotating beacons and flashing strobe light combination system worked well in both the stationary and the moving work zones.

This last set of findings illustrates some of the issues associated with the other function of vehicle flashing warning lights, that of proper information transfer to motorists and pedestrians. Whereas detection or perception of a warning light is

primarily physiological, information transfer is primarily cognitive. Here, the sensory information received through the visual system is converted to something meaningful through a pattern recognition process. Among other things, this process is highly dependent on driver expectations developed through past experiences, the means by which those experiences are coded in memory, and the context in which the information is received (*6*).

Color plays an important role in the memory coding and pattern recognition process. This fact is well accepted in the traffic engineering community, and is the main reason why traffic signs utilize standard colors to indicate different types of information (regulatory, warning, guide, and so forth). A similar rationale exists for assigning warning light colors to certain applications (hence, the restriction of certain light colors to emergency vehicles, and yellow to maintenance and construction vehicles). However, the assignment of a single color (yellow) to all maintenance vehicle applications implies to motorists that all types of situations in which these vehicles are used are equal in terms of their severity, hazard potential, and expected response. Whereas it may be perfectly appropriate to convey a single message for emergency vehicles (e.g., high-hazard emergency situation approaching), service vehicles are used to perform many different activities, some much more hazardous to motorists and workers than others. At the very least, it seems logical that some distinction is appropriate between those situations and activities that pose lower risk to workers and motorists and those that pose higher risk (such as those in which workers are out next to traffic, with little or no advance traffic control signing present).

In recent years, TxDOT has allowed a combination of yellow and blue lights to be used on certain vehicles during activities that are believed to be more hazardous to workers and motorists. In addition, light bars incorporating red, yellow, and blue rotating beacons and flashing lights have been allowed for use on TxDOT courtesy patrol vehicles in urban areas. Because red and blue have traditionally been limited to emergency vehicles, these practices have been questioned by law enforcement agencies out of concern for the possibility of an eventual degradation in public perception of and response to emergency vehicle warning light systems. From TxDOT's perspective, a policy allowing more frequent use of colors other than yellow for certain applications is obviously more complicated to maintain and administer and requires more effort to ensure compliance. Therefore, it is important to ensure that the use of additional colors provides a true safety benefit to workers and the public.

Over the past year, TTI and TxDOT have worked to determine whether the use of multiple colors is appropriate and justifiable for certain applications in TxDOT's vehicle fleet. These efforts have included a nationwide review of warning light color applications by other state DOTs, an investigation of motorist interpretations and perceptions of various warning light colors and color combinations, and studies to determine whether motorists respond differently to different color combinations in actual driving situations. The results of each of these efforts are summarized in the following sections.

NATIONWIDE WARNING LIGHT COLOR USAGE

Researchers contacted all 50 state departments of transportation (DOTs) by telephone to determine current warning light policies and practices for construction and maintenance vehicles, particularly with respect to the use of colors other than the standard yellow (or

amber). As expected, every state indicated that yellow was the primary warning light color utilized in its vehicle fleets. However, 12 states (24 percent) utilize at least one other color besides yellow on some equipment. Colors mentioned during the survey were as follows: blue (mentioned by seven states), red (mentioned by five states), and white (mentioned by five states). Although seven states indicated that they did utilize blue lights, four of them noted that this color was limited to use on snow removal equipment. Others indicated that the color was included in the light bar assembly mounted atop courtesy patrol vehicles.

Another question asked during these state surveys was whether the state agency had developed an official state policy regarding special vehicle warning lights for its fleet. Only 14 states (28 percent) responded in the affirmative to this question. Of course, since most states utilize yellow lights exclusively, they may have little need to establish formal warning light policies. Nonetheless, the survey results do suggest that most state DOTs consider their current vehicle warning light practices to be adequate.

MOTORIST INTERPRETATIONS OF WARNING LIGHT COLORS

Survey Description

One of the reasons for considering the use of colors and color combinations other than just yellow for special flashing warning lights on certain types of maintenance and construction vehicles is the assumption that these other colors imply a greater sense of danger or hazard to motorists. Traditionally, yellow flashing lights have been employed on vehicle warning lights, intersection beacons, and flashers mounted on signs and barricades in work zones. The level of hazard associated with these uses varies dramatically. Conversely, most states (including Texas) restrict the color of certain lights to authorized emergency vehicles. Intuitively, one expects that these restrictions teach motorists a flashing light color hierarchy over time (as they encounter the different types of emergency vehicles and their associated warning light combinations). However, it does not appear that these assumptions have ever been investigated in an objective manner.

Consequently, TTI researchers conducted a small survey of Texas motorists to determine their perceptions of different warning light colors and color combinations. The survey consisted of two parts. In the first, motorists were asked the following questions for each of several warning light colors or color combinations:

- If you saw flashing (color or color-combination) warning lights mounted atop a vehicle, how hazardous would you consider the situation you were approaching to be?
- What driving action, if any, would you take?

Possible responses to the first question were as follows: not hazardous at all, somewhat hazardous, moderately hazardous, very hazardous, or extremely hazardous. Possible responses to the second questions were as follows: no action, take foot off accelerator, tap brake, apply brake gently, or apply brake firmly. Researchers queried motorists on each of the following colors and color combinations: yellow, blue, red, yellow-blue, yellow-red, blue-red, and yellow-blue-red. Researchers ordered the presentation of the various

colors and color combinations to eliminate potential biases or the implication of increasing or decreasing hazard associated with a given order of presentation.

Survey Results

Motorist Perception of Warning Light Colors

Researchers conducted the survey at driver licensing stations in Houston and Fort Worth. In total, 209 survey responses were obtained. Table 1 summarizes the responses to the question about the level of hazard associated with each light color or color combination. The results do indicate that Texas drivers have learned a definite color hierarchy with respect to special flashing vehicle warning lights. When presented individually, yellow conveyed the least degree of hazard to motorists, followed by blue, and then red. When two colors were combined in one display, the yellow-blue combination represented a lesser degree of hazard than did the yellow-red combination or the red-blue combination. However, the yellow-blue combination appeared to represent a slightly more hazardous situation than did yellow considered alone. Finally, the red-blue-yellow combination was viewed as indicative of the most hazardous situations.

Corresponding to the results shown in Table 1, Table 2 presents a summary of survey responses as to the actions drivers should take when they encounter each flashing vehicle warning light color or color combination. The relative trends shown in Table 2 are similar to those in Table 1. Specifically, the responses associated with both the yellow and the blue lights tended to be less dramatic driving actions (e.g., no action or take foot off accelerator) than were the responses associated with the red lights (e.g., nearly 80 percent of the motorists surveyed felt they should apply their brakes gently or firmly when they encounter a vehicle with special red flashing warning lights on top). Furthermore, the yellow-blue light combination resulted in more frequent responses claiming the need for some type of braking action than did either the yellow or blue lights alone. However, the yellow-red light combination generated a slightly higher percentage of braking action responses than did the yellow-blue light combination. Finally, the driving actions associated with both the red-blue light combination and the red-blue-yellow light combination were nearly identical.

From the responses presented in Tables 1 and 2, it does appear that motorists associate less hazard or danger with yellow flashing warning lights than they do with other colors and color combinations. As a result, they also seem to perceive less of a need to slow down when approaching vehicles with flashing yellow lights than they do when approaching vehicles that have yellow combined with either red or blue lights (or both red and blue). For many activities that utilize construction and maintenance vehicles in a manner that does not present unusual risk either to workers or to the motoring public, this perception and response to yellow lights may be entirely appropriate. However, as stated previously, there also are many other maintenance or construction situations that pose significant risk to workers or motorists or both. For these situations, the use of yellow lights alone may not adequately convey the appropriate sense of hazard and urgency to motorists.

TABLE 1 Levels of Hazard Associated with Various Light Colors or Color Combinations

Flashing Warning Light Color or Color Combination	Percent of Motorists Responding			
	Not Hazardous	Somewhat Hazardous	Moderately Hazardous	Very Hazardous or Extremely Hazardous
Yellow	12	46	34	7
Blue	18	31	34	17
Red	1	11	20	67
Yellow-Blue	11	34	36	19
Yellow-Red	8	24	36	32
Red-Blue	4	12	33	51
Red-Blue-Yellow	3	13	28	56

TABLE 2 Driving Actions Associated with Various Light Colors or Color Combinations

Flashing Warning Light Color or Color Combination	Percent of Motorists Responding			
	No Action	Take Foot Off Accelerator	Tap Brake	Apply Brake Gently or Apply Brake Firmly
Yellow	10	35	14	42
Blue	15	28	15	42
Red	1	13	8	78
Yellow-Blue	9	25	18	48
Yellow-Red	6	21	16	57
Red-Blue	3	14	13	70
Red-Blue-Yellow	3	13	11	72

Motorist Association of Warning Light Colors to Specific Vehicle Types

The second phase of the survey was designed to investigate the types of warning light colors and color combinations motorists tend to associate with different types of emergency and other vehicles. For each vehicle type of interest to the surveyors, survey respondents were asked to write down the warning light color or colors they would expect to see mounted atop the vehicle. The vehicles examined in this phase of the survey included the following: police vehicles; ambulances; tow trucks; highway construction, maintenance or service equipment; fire trucks; and motorist assistance or courtesy patrol vehicles.

A summary of the major colors and color combinations that motorists associated with each of the above vehicle types is provided in Table 3 (the remaining responses were

distributed among various other color combinations or were not filled in by survey respondents). The results are consistent with Texas' current special vehicle warning light policies regarding color. Most motorists associate the color yellow with basic service vehicles (construction and maintenance, motorist assistance, or tow trucks). However, the percentage was somewhat lower for the motorist assistance vehicles (only 36 percent of motorists associated yellow with these vehicles). Approximately 10 percent of motorists also associate a combination of red and yellow flashing lights with tow truck operations.

With respect to emergency vehicles, it is interesting to note that motorists do seem to associate slightly different light color combinations with the different classes of these vehicles. For example, motorists cited a red-blue light combination most often for police vehicles (50 percent of those surveyed), whereas the single color red was more often cited for ambulances and fire trucks. In fact, only 12 percent of motorists associated the red-blue light combination with an ambulance, and less than 10 percent did so for fire trucks.

TABLE 3 Warning Light Colors Associated with Various Vehicle Types

Vehicle Type	Flashing Warning Light Color–Color Combination	Percent Responding
Construction, Maintenance, or Service Vehicles	Yellow	72
Motorist Assistance Vehicles	Yellow Blue	36 14
Tow Trucks	Yellow Yellow-Red	70 10
Police Vehicles	Red-Blue Red-Yellow-Blue Red-White-Blue	50 14 11
Ambulances	Red Red-Yellow Red-White Red-Blue	36 22 13 12
Fire Trucks	Red Red-White Red-Yellow	54 16 11

MOTORIST RESPONSES TO ALTERNATIVE WARNING LIGHT COLOR SCHEMES

Study Description

The survey responses suggest that motorists do indeed perceive differences in vehicle warning light color configurations, and that they believe they should respond differently to them. To determine whether these perceptions actually translate into differences in driver behavior, researchers conducted a series of field studies on five urban freeway sections in Houston and San Antonio, Texas. In each study, TxDOT maintenance or courtesy patrol vehicles were outfitted with different vehicle warning light color

combinations and placed, one at a time, on a shoulder next to moving traffic with the lights activated. Color combinations examined in this phase of the study were as follows: yellow lights only, yellow-blue lights, and yellow-blue-red lights. A fourth combination, consisting of yellow and blue strobes mounted in the back window of a TxDOT sport utility vehicle and strobes mounted in the rear taillight assemblies (operating in a simultaneous double-flash mode), was also tested at two of the sites.

Researchers videotaped traffic approaching the vehicle from 150 to 450 meters (500 to 1,500 feet) upstream (depending on viewing conditions) to determine vehicle speeds, traffic distribution by lane, lane-changing activity, and brake activations under each of the flashing vehicle warning light configurations. Vehicles were tested on either the left or the right shoulder at each site in either daytime or nighttime conditions (both daytime and nighttime conditions were evaluated at one site). Brake applications could only be determined during the nighttime studies, however.

Study Results

Effect of Warning Lights on Vehicle Speeds

Figure 1 presents a comparison of average speeds of vehicles passing the test locations when the different vehicle warning light configurations were being displayed. Sites are labeled 1 through 4, with letters in parentheses for each site location denoting whether the study was conducted during daytime or nighttime conditions (both daytime and nighttime data were collected at site 1). Because of poor lighting conditions, it was not possible to determine vehicle speeds from the videotape at the fifth test site.

At two of the five sites tested, vehicle speeds when the yellow and blue light combination was displayed were significantly (5–6 mph) lower than when only a yellow light was displayed. At the other three sites, speeds were not significantly different under these two warning light configurations. Interestingly, no statistically significant differences were found in average speeds at any of the sites when the yellow-blue-red warning light configuration was compared to the yellow-warning-light-only configuration. The yellow and blue strobes with red strobes in the vehicle taillights yielded a significantly lower speed at S1(d) relative to the yellow-only configuration. However, traffic volumes at this location had increased significantly during the time period in which this configuration was tested. Consequently, the reduction in speeds may have resulted in large part from traffic interferences rather than from the effects of that particular warning light configuration.

Effect of Warning Lights on Driver Lane Choice

Driver lane choices were also examined as a potential measure of performance regarding different vehicle warning light colors. Lane choice was evaluated both in terms of the percentage of traffic in the lane closest to the vehicle warning lights, and in terms of lane-changing rates away from the lights (within the camera field of view). Figure 2 presents the percentage of traffic in the lane closest to the flashing warning lights. Generally speaking, the different warning light color configurations had very little effect upon this performance measure. The only statistically significant differences detected occurred at S1(n), where lane

percentages adjacent to the various warning light configurations slightly decreased relative to the yellow light only configuration.

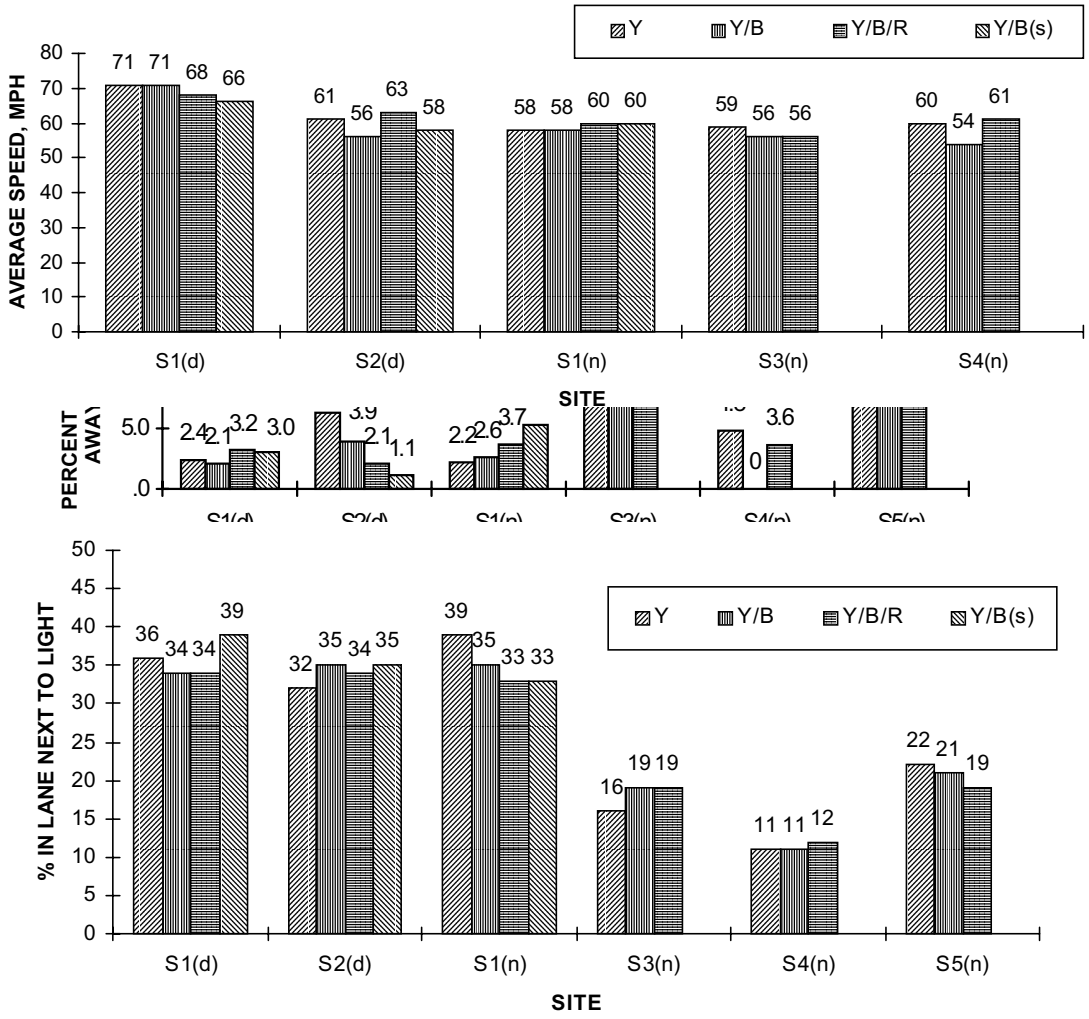


FIGURE 1 Effect of vehicle warning light colors on average speeds.

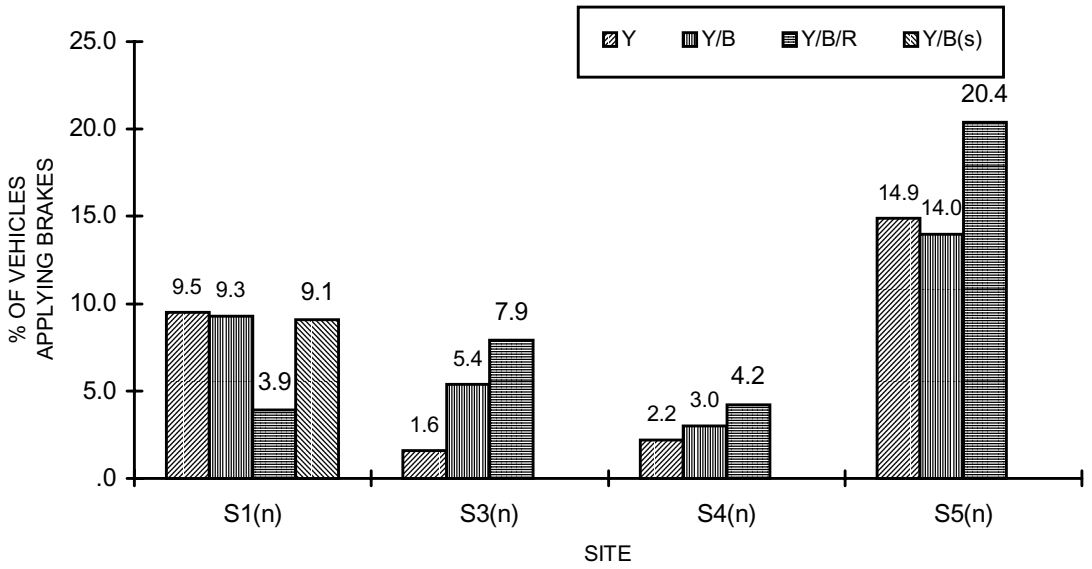
FIGURE 2 Effect of warning light colors on lane distributions.

Similar results were obtained when researchers examined lane-changing rates (within the video camera's field-of-view) as a function of the vehicle warning light color configuration displayed. As depicted in Figure 3, no clear trends in this performance measure are evident. One site did display higher lane-changing rates away from the lights when blue and red colors were used in conjunction with yellow light (in comparison to the all-yellow light configuration). However, this was not repeated at the other sites.

FIGURE 3 Effect of warning light colors on lane changing away from lights.

Effect of Warning Lights on Brake Activations

The final performance measure examined was the frequency of brake light activations for motorists approaching the various vehicle warning light color configurations. Because of viewing angles and video camera quality, these comparisons could only be made for those studies conducted at night. Figure 4 presents the percent of brake light applications under each configuration at each of the nighttime study sites. Unlike the lane-choice data, these



data trends were more consistent. At three of the four sites, the yellow-blue-red warning light configuration resulted in a higher braking percentage than the yellow light only. The yellow-blue configuration also resulted in a significantly higher braking percentage (relative to the yellow-only configuration) at one site. Although pavement illumination levels were not measured during these studies, it should be noted that fairly substantial overhead lighting was present at sites S1 and S4, and less so at sites S3 and S5. Furthermore, the study site S5 was located just over the crest of a hill, which further limited sight distance to the test vehicle. Interestingly, these sites were where the more significant differences in performance were observed as a function of warning light color. Researchers hypothesize that the relatively lower overhead lighting levels (and limited sight distance at one site) made it more difficult for motorists to determine the type of vehicle that was associated with the different warning light color configurations, thus causing more motorists to brake before they reached the vehicles. When overhead lighting was higher, motorists could see the type of vehicle and its location on the roadway ahead. In this situation, the warning light color configuration may have become a less critical information source for motorists, resulting in little differences in braking applications.

Although significant differences by warning light color configuration were not always present at each site, the presence of warning lights in general did affect braking application relative to a normal (no-warning-light) condition. This is evident in the fact that brake application rates at three of the four sites were significantly greater than zero for all warning light color configurations, including yellow only. At site S3, the braking

percentage associated with the yellow light only was not significantly greater than zero, but the braking percentage was significantly greater than zero for the yellow-blue and yellow-blue-red configurations.

FIGURE 4 Effect of warning light color configurations on vehicle braking.

SUMMARY AND CONCLUSIONS

The goal of the studies performed for this research project was to determine whether the use of warning light colors other than the standard yellow (amber) on construction and maintenance vehicles offers any potential safety benefit to workers or to the traveling public. Nationally, utilization of colors other than yellow is rather limited, although some states do use blue or red lights, or both, in conjunction with yellow lights for certain applications (such as courtesy patrol vehicles). Within Texas, survey results indicate that most motorists do associate yellow lights with highway construction and maintenance vehicles as well as with tow trucks, whereas light combinations involving red (red and blue, red and white, and red and other colors) are associated with the various types of emergency vehicles. Interestingly, motorists do appear capable of differentiating amongst different emergency vehicles because of the specific light color combinations that are used. In addition, motorists do appear to associate different levels of hazard and appropriate driving responses to different warning light color configurations. As expected, motorists seem to perceive yellow-only warning lights as indicative of less hazardous situations, in comparison to situations where vehicles utilize a combination of yellow lights with either blue or red lights. In turn, more motorists indicate a belief that these higher hazard situations necessitate some degree of braking action, in comparison to situations where vehicles use yellow lights only.

Field studies conducted in San Antonio and Houston examined the effect of yellow-only, yellow-blue, and yellow-red-blue vehicle warning light configurations on several operational traffic measures. Study results at two of the sites found that average speeds when a yellow-blue light configuration was displayed were 5–6 mph lower than when only yellow lights were displayed. However, speeds at the other three sites indicated no significant differences between those two configurations. Somewhat puzzling was the fact that similar results were not obtained for the red-yellow-blue light configuration. At all five sites, average speeds for that light configuration were not significantly different from the speeds measured when the yellow-light-only configuration was displayed. The yellow-blue-red taillight strobe configuration yielded lower average speeds at one site relative to the yellow-only configuration, but not at the other two sites where it was displayed.

Lane-choice performance measures examined in these studies were inconclusive as to any effects as a function of warning light color configuration. However, analysis of brake light applications did indicate a trend towards increased brake usage for the red-yellow-blue light configuration relative to the yellow-light-only configuration. There also was evidence that the yellow-blue light configuration may result in slightly greater frequency of brake applications, although not as dramatic as for the red-yellow-blue configuration.

From the perspective of a transportation agency such as TxDOT, concerned with the safety and welfare of its workforce performing tasks out in or near moving traffic, the results of these studies suggest that the use of yellow-only flashing warning lights may not correctly convey the true level of hazard associated with certain types of construction and maintenance activities. In particular, those activities that place workers out in traffic without the provision of advance warning signing or positive traffic separation with concrete or other barriers are particularly hazardous, and should be indicated to motorists as such. The results of these studies indicate that TxDOT and other transportation agencies should consider using more than simply the yellow vehicle warning lights during maintenance or construction that is particularly hazardous to workers or the motoring public.

ACKNOWLEDGMENTS

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). The authors would like to express their appreciation to the following persons who have served on the Technical Advisory Committee for this research project: Tony Arrendo, Jules Budny, Doug Chalman, Terry Eulenfeld, Ken Fults, Glenn Hagler, Toby Homuth, Lenert Kurtz, Codie Parkhill, Rich Rogers, and John Svab; all of TxDOT; and Major Lester Mills of the Texas Department of Public Safety.

REFERENCES

1. *Texas Traffic Laws*. Texas Department of Public Safety, Austin, 1997–1998.
2. Howett, G. L., K. L. Kelly, and E. T. Pierce. *Emergency Vehicle Warning Lights: State of the Art*, *NBS Special Publication 480-16*, National Bureau of Standards, U.S. Department of Commerce, Washington, D.C., September 1978, 165 pp.
3. Rubin, A. I., and G. L. Howett. *Emergency Vehicle Warning Systems*, *NBS Special Publication 480-37*, National Bureau of Standards, U.S. Department of Commerce, Washington, D.C., May 1981, 21 pp.
4. Howett, G. L. *Some Psychophysical Tests of the Conspicuities of Emergency Vehicle Warning Lights*, *NBS Special Publication 480-36*, National Bureau of Standards, U.S. Department of Commerce, Washington, D.C., July 1979, 20 pp.
5. Hanscom, F. R., and R. F. Pain. *NCHRP Report 337: Service Vehicle Lighting and Traffic Control Systems for Short-Term and Moving Operations*. TRB, National Research Council, Washington, D.C., 1990, 62 pp.
6. Klatzky, R. L. *Human Memory: Structures and Processes*. W. H. Freeman and Company, New York, 1980.

Development of Guidelines for Control of Radio-Frequency Interference

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OUTLINE OF THE PROJECT

Area of Research

Motor vehicle electromagnetic compatibility (EMC)

Sponsor

Texas Department of Transportation (TxDOT)

Time Line

Project will be completed by August 31, 1998

Background/Motivation

A. In the past, interference produced by electrical systems of some TxDOT motor vehicles limited the range of onboard two-way FM radios operating at low-band VHF.
B. To help combat the problem, a vehicle-interference test, Tex-899-B, was devised by TxDOT to screen vehicles.
C. New vehicles frequently failed Tex-899-B, requiring one or more custom modifications in order to pass.
D. Vehicle manufacturers have expressed concern over the problem but prefer to use an inherently simpler test like the Society of Automotive Engineers (SAE) test J551/4, rather than the Tex-899-B test, to check for vehicle interference.

Objectives

A. Evaluate the TxDOT Tex-899-B test.
B. Investigate the sources of vehicle failures to Tex-899-B.
C. Evaluate the SAE J551/4 test.
D. Devise a test like J551/4 that can be substituted for Tex-899-B.

Procedures

A. Perform Tex-899-B and J551/4 tests on several TxDOT trucks.
B. Perform bench tests on the immunity to interference of several TxDOT radios.
C. Use the highest quality laboratory equipment.

Results and Recommendations Regarding Tex-899-B

A. The Tex-899-B test should be carried out with the radio "noise blanker" circuit switched on (not off, as has been the practice); this is the normal mode of operation of the radio and it allows for greater immunity to interference.
B. The Tex-899-B test limit should be changed from "1.0 μV or 6 dB above ambient noise level, whichever is less" to simply "1.0 μV."
C. Following recommendations A and B above, all three brands of 1997-model pickup trucks– Chevrolet, Dodge, and Ford– were found to pass Tex-899-B.

Results and Recommendations Regarding the Relationship of J551/4 to Tex-899-B

A. The two tests are fundamentally different in nature: Tex-899-B, a "SINAD" test, depends on which FM radio is used, but J551/4, a "peak-noise amplitude" test, does not depend on the radio.
B. Our Tex-899-B tests employed the two most common TxDOT low-band mobile radios, GE RANGR™ and Motorola *MaraTrac*; other radios would probably perform similarly.
C. We are completing a final review of our data now; it appears that J551/4 can be substituted for Tex-899-B if the following modifications are made to J551/4:
    1. The limit on narrowband interference must be lowered from 1.0 μV to about 0.7 μV.
    2. The limit on broadband interference from spark ignition systems may be raised from 25 μV to at least 300 μV.
    3. The limit on broadband interference from DC motors (e.g., fuel pump, HVAC fan, and wipers) may be raised from 25 μV to at least 50 μV.
    4. The way in which broadband interference is distinguished from narrowband must be changed so as to make the narrowband category a bit less restrictive.
D. Assuming that SAE J551/4, as modified in C above, is acceptable to the vehicle manufacturers, it can be used to qualify future vehicles for TxDOT service.

Research in Support of State Equipment Fleets: Closer Than You Think

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Crane manufacturers and American Society of Mechanical Engineers (ASME) standards warn against side and shock loading on crane booms. Nevertheless, crane accidents at the North Carolina Department of Transportation (NCDOT) have demonstrated that these accidents are not uncommon and result in costly repairs. This paper discusses how a set of sensors and electronic devices was used to detect such unsafe crane operations. Once the situation is detected, the system gives a warning signal, and stores time and other pertinent data about the incident in a data storage device. This data can then be used to evaluate the reaction of the crane to these loadings. The success of the prototype has led the NCDOT to order a first production unit, which is presently being installed on a truck crane.

The second example of research results presented in this paper is the Buried Utility Detection System (BUDS), an innovative new prototype system that differs from traditional passive metal detection systems in that it is installed directly on excavating machinery. The objective of BUDS, an ongoing research effort, is to develop an effective and reliable system that can be attached to any type of utility digging equipment.

The third technology presented in this paper is a robotic bridge maintenance system, the result of a three-year effort. The removal of paints, especially those containing lead, is a hazardous and repetitive operation that could be executed more safely and efficiently using automation and robotics. The motivation for using advanced technologies in the general area of bridge maintenance is removal of laborers from dangerous work environments and reduction of time and cost necessitated by conventional methods.

INTRODUCTION

Safety is one of the most critical issues for the Department of Transportation. Advanced technologies offer new opportunities to provide safer equipment/work environment for the workers and the general public. The Construction Automation and Robotics Laboratory (CARL) at North Carolina State University (NCSU), in cooperation with the North Carolina Department of Transportation (NCDOT), has developed several prototype systems to test the applicability of these innovative concepts. This paper presents three of these prototype systems, used in the safe operation of cranes, the detection of buried utilities, and painting of bridge steel.

TRUCK CRANE MONITORING SYSTEM

Various field trips and interviews with supervisors and crane operators provided the necessary information for modeling common rigging operations that have led to crane damage in the past. Three main types of crane damage identified are grooves on the sheave created when the cable is winched while a load is being dragged, plastic deformation and failure of the boom (at the third section) due to overloading, and breakage of gear teeth in the turret drive due to turret overloading. These three types of damage can be associated with many failure modes. The first and the third type of damage are directly related to cable loads with significant components off the normal crane axis induced during dragging of loads. The second type of damage can result from overloading the boom by exceeding safe loading capacities specified in the capacity chart for different boom angles and extensions. In addition to the overloading case, another cause for possible boom failures has been identified: plastic deformation of the boom can result from the cumulative effect of static and dynamic forces that may occur during the abrupt extrication of lodged debris, piles, tree trunks, and so forth, in logging or clearing operations. After detailed observation and feedback from operators, it became apparent that many of these accidents were caused by insufficient or inaccurate information in the moment of decision making.

When operators decide to bring the crane into one of the unsafe loading situations, they are operating in uncharted conditions. Allowable boom angles, loading capacities, and boom extensions do not consider these types of operations. Consequently, crane operators and foremen have to rely on their perception of the situation and make decisions based on their experience. The foremen, who direct the lifting operation, have limited and oftentimes inaccurate information for predicting the exact mechanical effects (e.g., stress buildup in the boom cross section) produced during loading. One of the operators interviewed mentioned that being directly linked to the machine through the hydraulic control levers allowed him to feel certain vibrations and noises produced during overloading. Nevertheless, other operators felt that this type of feedback from the machine was not reliable for decision making. Many accidents prove this point.

In order to aid the operator in identifying unsafe conditions, overload protection systems based on hydraulic pressure limits are provided as standard in many new National Series 446A units. However, these overload protection systems will not detect unsafe conditions during dragging or extrication events. In addition, operators may choose to ignore the warning signals from the protection system and operate with dangerous hydraulic pressure levels. It is necessary to acknowledge that the uncharacteristic nature of the work and the demand on getting the job done encourage operators and supervisors to push the equipment to the limit.

Finally, the operators found it difficult to calculate actual loads on the job site. Many bridge maintenance operations involve pulling tree trunks, piles, and even water-filled vessels out of riverbanks. Any accurate calculation of the load on the hook would be difficult to determine in these cases. Aside from this fact, the weight of most of the items used for bridge repair and maintenance is unknown; therefore, the operator has to estimate the load at the moment of lift. Mistakes in judging appropriately lead to overload failures.

Definition of Critical Loading Cases

As a result of the discussed factors, three main loading cases have been identified and classified. Figure 1 presents a schematic representation of these cases:

Lift Case A: Vertical lifting (normal mode of operation),
Lift Case B: Dragging a load (results in nonvertical cable vector), and
Lift Case C: Abrupt extrication (pulling temporarily stuck objects).

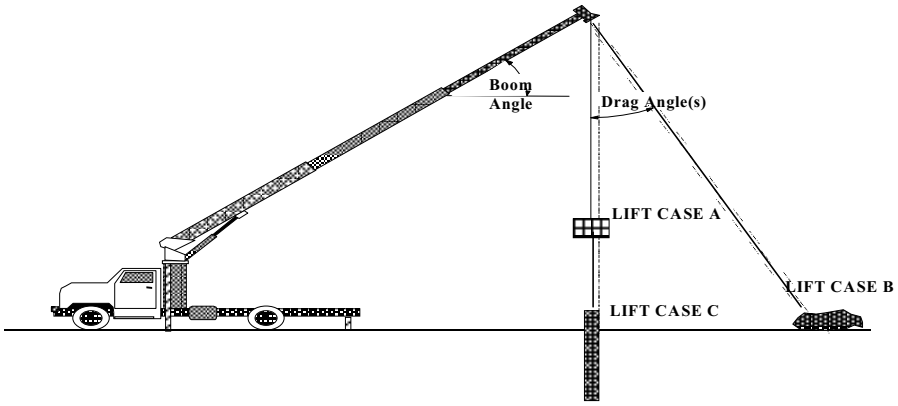


FIGURE 1 Schematic of three critical loading cases.

Lift Case A represents the intended mode of operation, namely lifting objects vertically. The stresses in the selected boom cross section for various boom angles during vertical load lifting were used as a baseline for a comparative analysis of the stresses encountered in the other loading conditions.

Lift Cases B and C represent situations that are not uncommon and may result in extreme stresses in the boom cross section, because they not only produce cumulative static forces, but dynamic forces as well. Also, it is felt that the three main types of damages to the boom and turret drive are related to these two loading cases, because they introduce significant additional forces for which the crane was not designed. A detailed stress analysis of these cases is necessary to support this qualitative assessment.

Turret drive failures are expensive to repair. While these damages are closely associated with Lift Case B, it is important to realize the special character of the loading situation that may lead to this type of accident.

Sensor Technologies to Detect Dragging

Three types of sensing devices have been tested to detect excessive dragging forces. The first one is a modified tip-switch (see Figure 2) mounted parallel to the cable at the sheave of the boom tip. This device is currently used to control the level of bulk material in silos. The second sensor is a load cell attached to the load line to measure force in the cable (used only during the experiments). Finally, a set of pressure transducers was installed in the hydraulic lines feeding the turret drive in order to measure pressure variations during dragging.

FIGURE 2 Close-up view of tip-switch mounted on boom tip.

The initial tests showed that the first and most direct indicator of load dragging is the tip-switch. This device can sense if the cable has been set in an excessive angle (e.g., more than 15° off the vertical). Nevertheless, only when the cable is loaded will this condition present a hazard to the crane. For this purpose, the main boom cylinder was equipped with two pressure transducers. The combination of these two sensors will provide the necessary information to identify the dangerous loading condition. The load cell attached to the load line was used to calibrate the pressure transducers. However, the two sensors will not be able to indicate if the dragging occurs perpendicular to the plane of the boom. Excessive pressure in the hydraulic fluid in the motor driving the turret would indicate dragging outside the plane of the boom. Also, the pressure transducers at the gearbox drive motor serve as a back-up technology in case the tip-switch is not working properly. In any case, the combination of these technologies should provide sufficient means for detecting any type of hazardous dragging conditions.

Sensor Technologies to Detect Extrication

Because of the speed with which the critical dynamic forces in the boom develop during extrication, it is extremely difficult to warn an operator within time sufficient to identify and avoid an unsafe lifting condition. Until the stuck object releases and starts moving in the direction of the pulling cable (e.g., the breaking of a root), the forces in the load line behave normally. The resulting acceleration of the object causes the boom, which is deflected downward, to deform instantly in the opposite direction. Consequently, the kinetic energy released results in an oscillation of the boom until it is dampened after a few cycles. The load, still connected to the cable, may drastically increase the accelerations and decelerations in the boom, causing it to bend or break.

It seemed highly unlikely that this critical loading situation would occur during an operator's first attempt at pulling on a stuck object. Crews working with the crane probably start with an easy object before they get bolder. The technologies tested to

protect the crews and the crane are based on such a scenario. Because it seems impossible to automatically detect this loading situation early enough, warnings can be given after the supposedly first “noncritical” attempt. Even though the warning comes after an occurrence, it might deter the operator and crews from undertaking a second and possibly fatal attempt.

Two interchangeable technologies have been tested for warning purposes: accelerometers and pressure transducers. An accelerometer, a device mounted on the boom tip, is able to detect rapid accelerations and decelerations, which are indicative of dynamic loadings. Once the analog output signal from the accelerometer is encoded, the corresponding digital reading is monitored by a microprocessor. Whenever an excessive value is measured, an audible alarm and a warning message on the operator monitor screen will be triggered. The second approach is based on monitoring the hydraulic pressure in the lift cylinder. Oscillation of the boom consequently causes abrupt changes in hydraulic pressure, and therefore, it is conceivable that the cyclic pressure variations can be detected by a set of pressure transducers integrated to the lift cylinder and interfaced with the computer, as was done with the accelerometer.

Interface Hardware

The interface components enable monitoring of crane conditions during the lift operation. Interfacing, as a function, comprises different levels of communication between sensors, computer, and human operator. The first level of interfacing comprises communication between the sensors and the on-line computer. This task is accomplished by encoding the analog signals from the sensors into a digital format. The device used for this purpose was designed and built by Elliott Technologies of Cary, North Carolina. All of the analog-to-digital conversions, as well as real-time processing of the digital data, are handled by this black box. A horn is used to alert the operator to dangerous conditions.

BURIED UTILITY DETECTION SYSTEM (BUDS)

Accurate location of pipes and cables without digging trial pits is a problem for utilities and highway authorities worldwide. Several gadgets now being used with varying degrees of success rely on transmitters plugged in to the buried service, magnetic field detectors, and ground probing radar. Most common of these search techniques is the magnetometer, which measures disturbances of the earth's magnetic field caused by ferrous objects buried in the ground. Such instruments sold as service locators are similar to metal detectors used by treasure seekers and make an audible beep signal. Interpretation of the signal depends on the skill of the operator.

Differing from most of the traditional metal detection techniques, the Buried Utility Detection System (BUDS) developed by CARL is an active search system. It consists of a metal detector search coil, a control box, an actuating device, and a PC computer with a data collection interface. The system generates its own magnetic field. Its impact on any metal object in its detection range will be picked up by the system. BUDS was developed and tested in the laboratory environment at CARL, and then installed on an excavator and a trencher. It consists of three major sub-systems: mechanical, hydraulic, and electrical. Figure 3 presents a schematic of the BUDS mounted on a backhoe excavator.

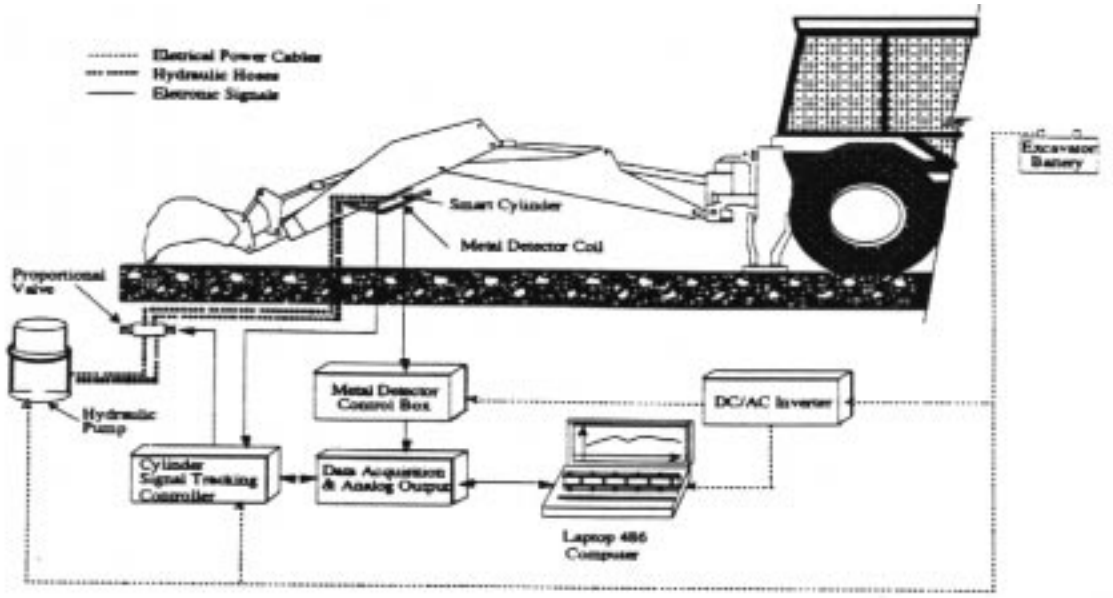


FIGURE 3 Schematic of BUDS mounted on backhoe excavator.

Field Experiments

The first experiments were carried out in a landfill managed by the City of Raleigh. A JCB model 1550B backhoe was utilized to "host" BUDS. Figure 4 shows the preparation of the backhoe in the field.

FIGURE 4 System setup for horizontal pre-dig scanning.

Excavation accidents involving the cutting of utility lines often happen during the backhoe's first dig. Therefore, a pre-dig detection of metal objects is considered necessary. Pre-dig detection focuses on scanning the ground, an action that basically imitates the traditional location operation from the surface. During the experiment, a 6.03-cm (2-3/8-in) diameter metal pipe was first buried approximately 33 cm (12 in)

below the surface. Figure 5 depicts the collected data during the pre-dig scanning. The vertical axis represents the metal detector output in millivolts (mV), which is proportional to the size of the metal object in combination with its distance from the coil. The horizontal axis corresponds to the sample number associated with the sequence of digitized analog signal obtained from the control box during the scanning process. In fact, the sample number is related to the positions of the boom in polar coordinates (angle).

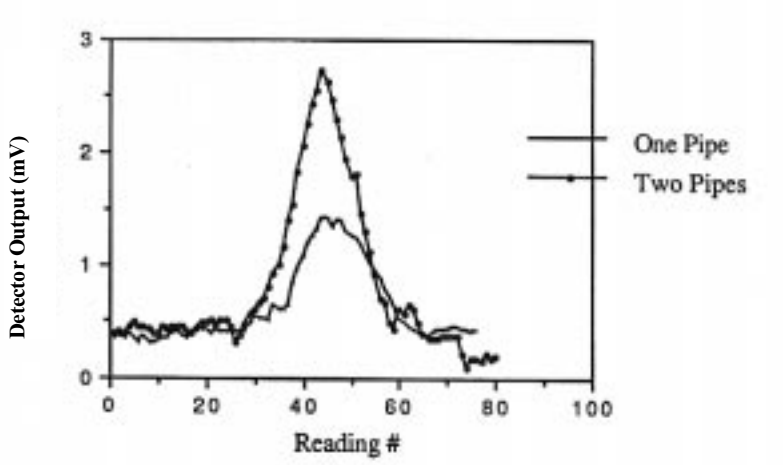


FIGURE 5 Data from pre-dig scans with buried metal pipe(s).

For the installation of television cables and household utilities, trenchers are the preferred digging machines. In order to evaluate the effectiveness of BUDS mounted on a trencher, experiments were conducted with a trencher provided by the City of Raleigh's Department of Public Utilities. While basically using the same concept as used in the excavator-mounted approach, the trencher does not require an actuation of the coil. Figure 6 depicts the installation of the metal detector mounted on a trencher, with which detection is performed while the operator is running the trencher.

FIGURE 6 Trencher-mounted BUDS.

Another use of the BUDS technology is locating of unexploded underground munitions. Figure 7 shows the scanning capability of the system mounted on a John Deere 690C.

FIGURE 7 Scanning capability of new BUDS.

ROBOTIC BRIDGE MAINTENANCE SYSTEM

The Robotic Bridge Maintenance System (RBMS) has four main capabilities: remote inspection, spray washing, paint removal, and painting. The basic goals of the system were elimination of the need for a human to become directly involved in the removal process and containment of lead-based paint. Additionally, the system was to be developed as an attachment to an existing under-bridge crane, thus reducing the cost of the system.

The RBMS was tested at the NCDOT Bridge Maintenance Facility in Raleigh, North Carolina (see Figure 8). The only modifications that were made to the truck were the routing of electrical and hydraulic cables along the boom and the installation of encoders on each of the boom joints. Each encoder provides angular position feedback for each boom joint so that the boom can be operated remotely.

FIGURE 8 NCDOT testing facility.

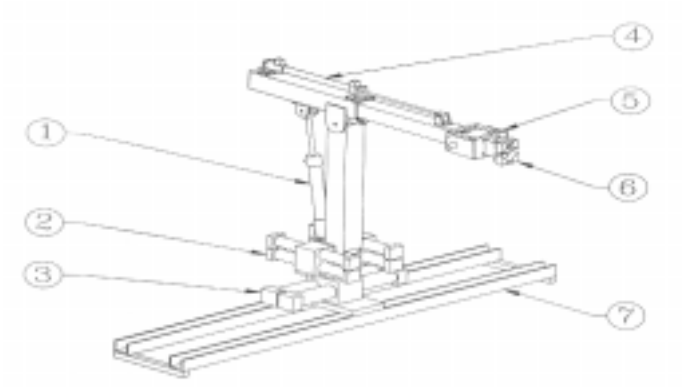
The bucket originally mounted on the end of the crane boom was removed and replaced with an articulated platform for the robotic system. Figures 9 (a) and (b) show the platform attached to the crane boom. The platform is hydraulically actuated with proportional valves, four cylinders, and one rotary actuator. Each of these actuators is remotely controlled via a computer with position feedback coming from the sonar sensors mounted on the track system and the crane boom. With this information it is possible to position and orient the robotic system within the workspace of the robot arm.

(a) Overall view (b) Close-up of articulated platform

FIGURE 9 Articulated platform for robotic system.

A track system was mounted on the articulated platform. The robot mounts to a trolley on top of the tracks, which provides lateral motion for spray-washing, sandblasting, and painting procedures. Underneath the tracks, a second trolley is mounted, to which the containment system is attached. Each trolley is moved independently with a hydraulic rotary actuator and a chain drive, with a potentiometer mounted on the shaft for feedback to the computer about the position of the trolley along the tracks. When the robot and the containment system are required to move simultaneously, the coordination is provided through the computer software.

A hydraulically actuated robot was designed and built at the Precision Machine Shop at NCSU. The robot, shown in Figure 10, has five degrees of freedom and was designed to reach into tight areas. The hydraulically actuated five-degree-of-freedom robot is mounted on a track system attached to the end of an under-bridge crane. The five degrees of freedom are provided by cylinders 1–5 shown in Figure 10. An additional sixth degree of freedom is provided by the tracks.



1. Elbow pivot cylinder
2. Shoulder rotation actuator
3. Shoulder roll actuator
4. Arm telescopic cylinder
5. Wrist pitch actuator
6. Pneumatic gripper
7. Track system

FIGURE 10 CAD drawing of new robot.

Containment System

The sand and debris are removed from the containment system (see Figure 11) through a funnel system leading to a 15.24-cm (6-in) vacuum hose that is mounted at the bottom of the primary box. The debris is drawn into this hose and brought to the top of the bridge by use of an 8.2-kW (11-hp) gasoline-powered vacuum. This system provided adequate transfer of the particles from under the bridge to the bridge deck. In this prototype, the vacuum used did not contain any filtration devices. It was used simply to demonstrate the capability of the containment system.

FIGURE 11 Overall system deployed.

To demonstrate the adaptability of the RBMS to the operation of different tools, a carbon dioxide pellet accelerator developed by Oak Ridge National Laboratory was mounted on the robot arm as shown in Figure 12. This device accelerates dry-ice pellets to velocities of up to 350 m/s and volumes of up to 454 kg/hr. These high-velocity pellets cause impact on a surface; in this case they remove paint chips. The 14.9-kW (20-hp), 12,000-rpm centrifugal cryoblaster weighs about 45.4 kg (100 pounds), making it an ideal candidate for integration with a hydraulically actuated robotic system. Since the

accelerator was much heavier than the other maintenance tools that were used, it was necessary to modify the robotic mount. In this case, the pneumatic gripper was not used since it was not capable of handling such a high payload. Instead, the accelerator was mounted to a plate bolted directly to the hydraulic wrist actuator.

Robotic manipulation is necessary, because it is not possible for a human operator to carry the system due to its weight and its operating speed of 9,000 rpm. The two systems complement each other very well. Testing showed that the cryoblaster could be mounted and successfully run from this robotic platform. Paint was removed from a beam. Sand blasting still produces a more suitable surface, but the future looks bright for the advancement of capabilities in dry-ice blasting of steel for paint removal.

FIGURE 12 CO_2 pellet accelerator mounted to RBMS.

SUMMARY

As shown in this paper, state equipment fleets can benefit greatly from technology advancements. The main advantage of these advancements is in the area of safety. The three examples shown here demonstrate the increase in safety that results when operators are better able to avoid dangerous situations, when costly or deadly underground utility damage is prevented, and when workers are moved to safer locations to perform unhealthy tasks such as removal of lead paint from bridge steel.

Skill-Based Pay Program for Mechanics

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North Carolina Department of Transportation

Human resource professionals constantly hear from management about the need for flexibility in pay systems. Managers frequently stress that it is too difficult for positions to be reclassified within narrowly defined classification structures. In 1993, the chief engineer of operations for the North Carolina Division of Highways (NCDOH) requested that the North Carolina Department of Transportation (NCDOT) Personnel Office conduct a classification study of maintenance employees. Working in conjunction with the Office of State Personnel and technical work groups representing the four highway operations functional areas (highway maintenance, bridge maintenance, traffic services, and roadside environmental), the NCDOT Personnel Office developed, and is currently piloting, a skill-based pay (SBP) program.

The program affects approximately 4,000 employees. Some of the objectives of SBP are flexibility, generic and broad classifications, equity, career development, and market competitiveness. The program also links with the performance management system. One goal of SBP is to encourage employees to gain skills the employer can put to use, thereby helping employer and employee alike. Different skills are grouped into skill blocks, each with its own compensation value. A key point is that the skills must be used on the job—not just obtained by the employee. Once an employer can put an employee's new skills to use, that employee is eligible for additional compensation. As NCDOT moves ahead with its SBP initiative, several other DOH areas are being considered for a similar program (e.g., mechanics and construction technicians).

This paper covers SBP basics, such as processes, structure, and results of the NCDOT program, along with information on how this program may be applied to other areas such as mechanics.

PROGRAM OVERVIEW

Skill-based pay (SBP) has been utilized by many private organizations that also use pay options such as merit and gainsharing. SBP appears to work best when an organization needs a flexible, multi-skilled work force that is compensated based on depth or breadth of skills performed. This compensation approach differs from the traditional "whole-job" compensation approach now utilized by state government.

An SBP program, also referred to as knowledge-based pay, is designed to encourage and reward employees for the acquisition of skills needed by an organization to increase efficiency and flexibility. This program provides a way for an employee to progress through a pay range based on the employee's added value to the organization. Employees are paid based on the number of skills they can perform. It should be noted that additional compensation would not be awarded for an employee's mere completion of training; additional compensation is not awarded until the employee has been assigned additional duties based on his or her newly acquired skills.

Skills are grouped into *skill blocks*, tasks or groups of duties that are smaller than whole jobs. Thus, a traditional "whole job" may represent several skill blocks. The skill blocks may represent horizontal or vertical skills. Potential benefits of implementing an SBP program include greater productivity; improved quality of work; greater cross training of the work force; a flexible, multi-skilled work force; higher levels of pay satisfaction among employees; and higher employee performance.

Research has shown that SBP is most useful and productive in a work environment where organizational performance depends upon good coordination and teamwork among individuals. It is useful also for situations where cross training or a multi-skilled work force is needed to cover continually increasing workload without increasing staff levels. In addition, some organizations are now utilizing SBP for individual whole jobs or an individual classification in which employees work more independently.

SBP can increase efficiency by several means. It can allow employees to cover for absenteeism and turnover, it facilitates shifting of tasks or assignments depending on workload demands, and it can provide better customer service or delivery. SBP appears to work better in organizations with a participatory management philosophy that stresses employee involvement in decision making. Even if an organization does not have this philosophy, horizontal SBP can address service and efficiency issues in a way that will allow the organization to do more without increasing staffing levels. By using SBP, the organization also allows employees to receive increases in pay, which may lessen turnover, allow greater job satisfaction, and lead to better job performance. SBP may also be an advantage in those organizations where the organization either has created or wants to create a flat rather than hierarchical organizational structure. If an organization wants to eliminate layers of supervision, it may do so through development of a more skilled and multi-talented work force that requires less supervision, as well as by giving employees more authority to make decisions.

However, an SBP program has some costs that an organization must be willing to absorb. For example, an organization must be willing to invest money and time into employee training (on-the-job or formal classroom development training, or both) to build employees to the described skill levels. An organization also will need to accept the fact that it may not have the most qualified employee performing the work on every job.

NCDOT needed to develop a flexible and multi-skilled work force to meet the anticipated challenges of declining personnel resources, increased contract administration, and continuous increases in maintenance of existing and new paved roads. Therefore, the Office of State Personnel (OSP) proposed an SBP program in lieu of conventional range revisions to achieve NCDOT's personnel goals. NCDOT and OSP began developing the SBP program in the fall of 1995 with significant input and support from NCDOT field and central maintenance management, as well as from representatives of other State agencies.

As previously mentioned, the goal of SBP is the development of an employee with diverse skills in a given operational area. SBP enables career-ladder opportunities and
provides management with a flexible tool for developing an efficient and multi-skilled work force. To accomplish this goal an SBP concept was developed:

SBP Concept: Base Job
+ Training
+ Skill Certification
+ Assignment and Performance of New Duties
= Skill-Based Pay

Unlike traditional class series, employees in NCDOT's SBP program remain in the same broad class, that of Transportation Worker. The following provisions govern salary increases for employees:

- Employees receive incremental increases as they attain new skills and are assigned new duties. These increases conform to the State's In-Range Salary Adjustment Policy, which limits pay increases to 10 percent per year.
- When duties for which salary increases have been awarded are removed, employee salaries are reduced. Employees are informed of this prior to entering the SBP program.
- Employees who do not progress in the program due to their capabilities, lack of desire, or lack of organizational need will not receive increases under the program. Increases for these employees will be limited to salary increases granted by the Legislature.
- Employees' salaries will be measured against prevailing market rates on a regular basis. If needed, salary rates will be adjusted to conform to changing market conditions.
- Employees exiting the SBP program and moving into higher-level classifications are subject to the New Hire provisions of the State Personnel Pay Policy.

DEFINITIONS

- *Base job*: A general range of duties and responsibilities as outlined in a position description and class specification.
- *Skill base*: The value an employee adds to a job by his or her ability to perform more diverse or complex skills above and beyond the general job concept as well as the value added to the organization in its ability to more efficiently complete operations by diversifying job tasks. The savings come from pooling (potential) and mobilizing (actual) diverse skills.
- *Skill-based pay*: Eligibility for increase in salary within a salary range that depends on management's recognizing of individual employee skill development and the agency's need to employ new skills in ongoing operations. The intent of skill-based pay is for compensation of work performed. Training accomplished is not equivalent to work performed.
- *Skill blocks*: Tasks or groups of duties that are smaller than whole jobs. Skill blocks may represent horizontal as well as vertical skills. Skill blocks are sets of tasks deemed operationally significant by NCDOT management. Each task has a relative internal value and corresponds to a training and/or certification opportunity provided or facilitated by NCDOT.

- *Skill-based pay administration*: Agency documentation that registers an employee's progress in a skill block and indicates specific activities for which the individual is being compensated.

RULES, CONDITIONS, AND LIMITATIONS

The following provisions have been established for allowing employees to participate in Maintenance-sponsored SBP training:

Employee shall have a "good" or better performance management evaluation and not be under disciplinary action of any type. For the purpose of this policy, the definition of *good attendance* is an employee's not being placed on leave-without-pay status during the preceding evaluation period. Exceptions to this policy are

1. Any employee who has been forced to go on leave-without-pay status due to personal illness as covered or defined by the Family Medical Leave Act (FMLA).
2. Any employee who has been forced to go on leave-without-pay status due to a family member's illness as covered or defined by the Family Medical Leave Act (FMLA).
3. Employee shall have a good attendance record—disciplinary action for abuse of leave may be a determining factor, as may be the number of times an employee is placed in leave-without-pay status over a certain period of time.
4. Employee shall have a good safety record—disciplinary action for incidents may be a determining factor, as may be number of incidents over a certain time period.
5. Employee shall satisfactorily complete any prerequisite courses or training.
6. Training shall be limited to that training applicable to employee's work unit.
7. Training of an individual shall not interfere with the overall production of the work unit.
8. Employee's length of service, experience, equipment operation proficiency, and production shall be considered when employee is being evaluated for possible advancement to the next level in conjunction with the complement system. The complement system will ensure that there is a correlation between the type of equipment used in an operation and the number of employees required for performance of work associated with the equipment.
9. Employee may complete only two equipment training courses per year unless approved by the division engineer.
10. Make sure there is or will be a need for a piece of equipment before training an employee to operate it.

CERTIFICATION PROGRAM

Training is a key element, a foundation of this program. NCDOT is committed to providing an extensive training program for all its employees. However, the accessibility of training will depend on two elements: needs of the organization and the individual's motivation to learn new skills. Training is supported by comprehensive guidelines addressing many issues, including certification and recertification of skills, selection for training, and training documentation and information flow.

The SBP training program has been developed for all employees who occupy positions under the classification of Transportation Worker, as identified during the DOH Maintenance Personnel Classification Study. The training is documented on special forms; these forms serve to support an understanding between the employee and supervisor concerning the specific training to be provided and the milestone(s) to be achieved.

Employees may receive training by following one of the following tracks to satisfy part of the skill block requirements: these tracks are Outside Training, Equipment Training, and Non-equipment Training.

Some skill blocks require employees to receive training and certification outside the Department. For example, in order to work inmates, maintenance employees receive training from the Department of Corrections. Traffic Services employees may receive training from the International Municipal Signal Association (IMSA). Some Roadside Environmental employees receive a pesticide license from the North Carolina Department of Agriculture and Consumer Services. The American Crane Institute must certify bridge maintenance crane operators. Two of the three tracks, Equipment and Non-equipment, often require employees to train under a mentor or on-the-job-training instructor.

SBP PROCESS

The SBP program utilizes four phases: course work, on-the-job training, certification, and compensation. Once employees enter on duty, they go through a process to identify the usable skills they are bringing to the Department. Once the employee completes a probationary period, he or she begins to participate in the SBP program by moving into the course work phase. During this phase, the following actions take place: supervisor and employee meet; skill blocks are identified; employee is assigned a self-study workbook for the appropriate skill block; employee takes a written test; and upon successfully passing the test, employee moves to phase II.

During phase II the employee is assigned to an on-the-job-training (OJT) instructor or mentor, who begins competency training and observes the employee for attainment of competencies. Once all competencies are mastered, employee moves to phase III (certification).

In phase III, a certified training coordinator checks the following: reports completed by the mentor, test grades, competencies, and skill block time requirements. This process documents employee progress toward satisfying specific requirements. Objective evaluation criteria and standards have been established for all training elements and components that require demonstration of appropriate skills. These criteria are used in the certification process to ensure fair and consistent treatment of all employees and to guarantee that all employees who satisfy a particular certification will possess the necessary skills and knowledge to carry out the related program work. When the certified training coordinator is satisfied, he or she signs appropriate documentation and submits appropriate forms to the personnel office.

The employee then enters phase IV (compensation). Compensation associated with this program occurs twice a year according to the performance appraisal cycle (i.e., around the middle of May and the first part of November).

POTENTIAL USE OF SBP FOR MECHANICS

Skill-based pay programs appear to work well for trades-related occupations. This is thought to be because there is normally a clear delineation between levels of work—as well as because existing certification programs can be used in conjunction with SBP programs, and labor market data is readily available for determining skill block values. The NCDOT is considering expanding SBP to other occupational areas. Several managers have indicated a need for developing an SBP program for their mechanics. It has been several years since the classifications and salaries of mechanics have been reviewed. It also was suggested that the Department consider utilizing existing certification programs such as the National Institute for Automotive Service Excellence (ASE) in conjunction with SBP. Several other states currently have certification programs for mechanics in place. In fact, the Virginia Department of Transportation is piloting an equipment technician series SBP program. Most state classification systems already cover the main mechanic functional responsibilities (i.e., service, replacement, repair, and rebuilding of components). The current practice in the private sector appears to be classification of service personnel as technicians, rather than as mechanics. This seems to be more in line with today's highly sophisticated and technically oriented service work.

As technology is continuing to have impact on these jobs, especially in the area of electrical systems and accessories, diagnostic responsibilities have come to the forefront. There is also a good tie to the SBP program for maintenance employees who operate equipment (mechanics are usually expected to road test highway equipment once necessary repairs have been completed). The Department believes that the time necessary to implement an SBP program for mechanics would be much shorter. Many of the processes and procedures would be similar to those of the existing SBP program. This would ensure that all employees are treated equitably.

If an organization has a large number of senior-level employees at the top of their pay ranges, SBP may allow them to learn new skills and receive additional compensation in the form of bonuses or base pay adjustments. However, SBP also can lead to resistance among senior employees who do not have the ability or desire to learn new technologies or skills. In designing the SBP program for mechanics, management must assess the needs of the organization and analyze the current workforce skills available to meet those needs. These actions will allow management to determine the need for an SBP program and its design. Development of a skill-acquisition plan would be necessary in order that each employee could acquire the skills needed.

When skill blocks are priced, each skill block contained within a whole should reflect the value of that skill block, based on the best information available. In other words, there must be a way to index the skill block to the appropriate labor market. The following questions will need to be answered prior to embarking on a Mechanics SBP project:

1. Who will determine the necessary skill blocks and competencies?
2. Who will develop the requirements for skill blocks?

3. Who will develop the training and the certification initiatives? Who will participate?
4. What effect will training have on overall productivity?
5. Who will certify employees?
6. What types of automation will be necessary to support this program?
7. How can the organization ensure all employees are treated fairly and equitably?
8. Who will handle salary administration?
9. What groups are competing for the organization's labor resources?
10. Is there a way to collect and analyze salary information to ensure proper matches based on comparable responsibilities?
11. How will the new pay structure fit in with existing policies?
12. What implementation strategies will need to be completed?
13. What is the organization's ultimate goal?
14. How will program success be measured?
15. How much will the program cost?

The New Art of Hiring Smart: Matching the Right Person to the Right Job

Arlen T. Swenson
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In his book, *Right Person—Right Job*, Chuck Russell wrote: "Core personality is made up of traits that have been conditioned over many years. Such traits are critical in assessing a candidate's ability to perform virtually any aspect of any job" (*1*). Albert Einstein once said you cannot solve problems with the same kind of thinking that you used to create them (*2*).

If you keep on doing what you have always done, you will keep on getting what you have always gotten. Organizations and businesses spend an enormous amount of time and money in a neverending effort to train, coach, motivate, or develop marginal employees to a level of performance that is merely adequate. In organizations and businesses throughout the world, there are people who are not performing at the levels expected. At some time or another, virtually every person has been in a job that was not right for him or her. All the same, organizations hired each of these people with careful thoughts and positive expectations. Most people took those same jobs with every intention of succeeding.

It is very difficult and expensive to train your way out of a bad hiring decision. The process by which individuals are selected is clearly the most critical and controllable variable in the development of a productive and successful work team. However, traditional selection methods have several limitations for the accurate understanding of people and their performance. Traditionally, organizations have viewed people and their performance within the context of ability. Those with lots of ability can do almost anything well, and those with less are often assigned to jobs in which they won't cause significant damage. This type of thinking supports the belief that education, experience, training, and more training will enhance ability and, therefore, performance. If a person with perceived ability does not perform well after being trained, his or her problem is assumed to be motivational.

CORNERSTONES OF JOB PERFORMANCE

In reality, three factors may have impact on a person's ability potential: attitude (organizational match); technical competence (skills match); and cognitive ability, personality structure, and interests (job match).

Organizational Match

Organizational match is the degree to which the candidate's attitudes, values, ethics, and grooming fit those required by the job position. Face-to-face interviews are typically used to evaluate these things. Being honest, drug-free, and not prone to hostility are also important factors, and are usually determined by use of various paper-and-pencil, electronic, and chemical tests, as well as by background checks. The perception,

intuition, and experience-based observations of a well-trained interviewer are invaluable in assessing certain qualities of attitude and match with an organization's culture. There are problems, however, with relying wholly on the face-to-face interview process.

One such problem, the halo effect, occurs when the interviewer sees a part of himself or herself in a job candidate. The interviewer may focus on a common experience, part of growing up, school, or some other aspect of background that he and the applicant share. A similar personality characteristic in the interviewee could generate a positive feeling of recognition within the interviewer. This self-recognition generates a "halo" that can cause a relatively mediocre candidate to glow with merit. On the other hand, another potential pitfall of the interview process is the unconscious bias, which is the opposite of the halo effect. The more a candidate is different from the interviewer, the more conscious effort is required on the interviewer's part to regard the candidate in a positive or neutral light. This is a fundamental characteristic of being human: when a candidate appears to be different in some way, there is always some effect. This effect may be large or small, good or bad. The important thing is that interviewers recognize the subjective nature of face-to-face interviewing.

Unfortunately, outstanding verbal and communication skills during an interview—or their opposite, lackluster responses—do not necessarily translate into job performance, just as the ability to talk knowledgeably about baseball and look good in a uniform would not necessarily translate into the ability to throw or hit a 95-mph fastball.

Skills Match

Skills match is the degree to which a candidate's educational background, technical skills, previous job experience, and particular expertise matches those required for the position. There are many job positions that demand specific sets of knowledge or technical skills. Research has shown that people charged with selecting for these positions are often tremendously biased toward thinking that expertise highly important. On a broader scale, one of the common hiring myths is that highly intelligent people can do anything. Job match research has proven that people actually perform best when they are fully engaged by the challenges of a job. Unless highly intelligent people are provided with a steady source of intellectual challenges, they may not only become poor performers, but may even become counterproductive.

If organizational match or skills match, or both, are unsatisfactory, improvement of an individual's long-term job performance with training or coaching is almost impossible.

Job Match

Job match is an integral part of a candidate's actual on-the-job success. Job match refers to how well an individual's cognitive abilities, interests, and personality traits match those required for success in a particular job. To illustrate, let's paraphrase the parable "Let the Rabbits Run," from the book *Soar With Your Strengths* (*3*):

> There were several young animals in the forest: a duck, a fish, an owl, an eagle, a squirrel and a rabbit. Each told his parents he wanted to go to school to improve

himself. The parents thought this was a good idea. They enrolled the young animals in a school with a curriculum of running, jumping, swimming, tree climbing, and flying.

On the first day of school, the little rabbit got up early to be in school on time. He brushed his teeth, combed his hair, ate his breakfast, and went to school with high expectations and excitement. His first class was running. He did great! His teacher told him he was a wonderful runner, and he got an A+ and his self-esteem got a boost.

The next day, the little rabbit went to jumping class. Again he did very well, received compliments from his teacher, and got an A+ and a boost to his self-esteem. The day after that, the little rabbit went to swimming class. He wasn't very good at it. His teacher said he didn't do very well at swimming, gave him a low grade, and told him he had to *learn* to enjoy being wet. His self-esteem suffered. The little rabbit was determined to succeed. For two weeks, the rabbit tried as hard as he could, but he just couldn't get the knack of swimming. He became discouraged and began to lose interest in school.

The rabbit was called to the principal's office with his parents. He was told that he was failing swimming class. As a remedy, the principal and the little rabbit's parents decided that he would be taken out of the running and jumping classes (because he could already do these things so well) and instead would be assigned to three swimming classes each day. The little rabbit tried to improve his swimming, but eventually became totally discouraged. When he was told that flying classes were next, he dropped out of school.

"Let the Rabbits Run" illustrates what happens when managers try to train their people for tasks or skills that are foreign to who they are. Knowing an individual's strengths and weaknesses, a manager can amplify (on the job) that person's strong points while minimizing (or avoiding) weak areas, thereby helping build the employee's self-esteem and increasing his job performance. A manager who hires a person without a natural job match and thinks he can overcome the new hire's shortcomings with training might as well be trying to train a rabbit to swim instead of hiring a fish.

The degree to which a candidate's cognitive abilities, interests, and personality fit those required by a particular position determines the degree of job match. People fail in a job not because they can't do the job, but rather because they don't match the job.

Cognitive Abilities

Cognitive abilities are factors such as how quickly a person learns and what type of learning is most effective. In a business sense, this is a far more useful measurement than what is generally called intelligence. It is critical to match an employee's cognitive abilities with those required for the job. For example, exceptionally fast problem solvers thrive in a challenging environment. When placed in relatively routine situations, these same people quickly become bored, resulting in low performance or unexpected turnover. In comparison, slow learners become frustrated in environments that do not allow sufficient time to assimilate key information about the job.

Interests

Whether a person has an interest in or preference for working with people, data, or things is important. An individual may be capable of performing certain tasks, but may not be interested in those tasks. If that is the case, the person will probably not perform the tasks well for very long.

Personality

Personality of the candidate consists of measurable characteristics of behavior that determine how an employee will behave in particular situations. Core personality is made up of traits that have been conditioned over many years. Such traits are critical in assessing a candidate's ability to function as part of a team, ability to close, ability to make decisions, ability to handle customers, and ability to perform virtually any aspect of any job.

Understanding organizational match, skills match, and job match is integral to understanding job performance. Each is a necessary part of any hiring or performance-enhancement decision. The idea of predicting job performance through the use of assessment tools has long been a dream of the business world, and until recently, an elusive dream. With the advent of fifth-generation assessment tools, organizations and businesses now have an instrument that offers remarkable accuracy and reliability, enabling information to be used in a number of applications that were not possible with older technologies. If management can acquire better information on people, it will inevitably make better decisions.

ASSESSMENT TOOLS

First-generation assessment tools have two fundamental problems: they are easy to fake and they are *ipsative* (describing tendencies without using any point of reference). Second-generation tools add some evaluation elements that are *normative* (using established units of measure), but most are still ipsative. Third-generation tools offer vast improvements; however, the normal manager cannot use them because they must be administered by licensed psychologists, and further, they contain questions that legally cannot be asked of employees, or on job applications. Fourth-generation tools do measure cognitive skills and personality characteristics; however, the fact that their validity base was developed in 1972 causes significant validation errors when current applicants and employees are measured for the twenty-first century. In addition, several scales in the mental abilities section measure *crystallized knowledge* (specific knowledge that is dependent on cultural environment and education) versus *fluid knowledge* (fundamental reasoning ability independent of specific content).

Fifth-generation assessment tools, which produce quantified scales (normative) and evaluate the total person, can be used accurately and effectively by non-experts to generate job patterns. Developed in compliance with legal requirements of the United States, Canada, and Great Britain, fifth-generation instruments can also serve to document nondiscriminatory hiring practices. Fifth-generation tools measure

- Mental abilities (cognitive—can the person do the job?),

- Interests (conative—is the person interested in doing the job?), and
- Twenty-four personality factors. (Does the person have what it takes to do the job and does the person fit the organization's culture?)

TABLE 1 Recommended Applications for Generations of Assessment Tools

APPLICATIONS	GENERATIONS				
	1st	2nd	3rd	4th	5th
Career Development	★	★	●	✕	★
One-on-one Counseling	★	★	●	✕	★
Pre-Employment Selection	✕	✕	✕	✕	★
Interviewing	★	★	●	✕	★
Promotion Decisions	✕		●	✕	★
Simple Team Building	★	★	✕	✕	★
Team Engineering	✕	✕	✕	✕	★
Sales Strategies		★	✕	✕	★
Performance Problems	✕	✕	✕	✕	★
Day-to-day Management		★	✕	✕	★
Training Strategies		★	●	✕	★
Re-Engineering	✕	✕	✕	✕	★
Right Sizing	✕		✕	✕	★
Clinical Diagnosis	✕	✕	●	✕	✕

★ RECOMMENDED ● PROFESSIONALS ONLY
OPTIONAL ✕ NOT RECOMMENDED

LEGALITIES OF USING TESTING AND ASSESSMENTS

The reality is that the proper and consistent use of effective testing and assessment systems can dramatically strengthen an organization's legal position. Job-related testing and assessments are essentially the only ways to document objective and nondiscriminatory hiring practices. In the three parts of the selection process, the area most susceptible to bias or discrimination is organizational match, which is largely determined by interviewing. Only the testing components are purely objective. Skills match may or may not be measurable, depending on the job.

Only job match, when measured by the proper assessment instrument, is completely objective. As Joyce Hogan, in *Employment Tests: History and User Considerations*, correctly points out,

> *Bias is a social component of the decision-making process, not a feature of the test results; therefore a primary advantage of test use is that tests, unlike interviewers, are incapable of being prejudiced by the applicant's race, gender, ethnicity, national origin, religion, age, or disability.* (*4*)

It is inconsistent with the spirit of (EEOC) and Americans with Disabilities Act (ADA) (*5*) legislation to hire a person for whom the probability of reasonable success in the job is limited.

In the selection process, the greatest advantage of assessments is the potential use of the information that results to predict the future performance of applicants. Under the Uniform Guidelines on Employee Selection Procedures (1994), a selection process must provide fair and equal employment opportunities to all applicants. Testing may be used

1. To screen out those applicants who are not likely to be able to perform the job successfully,
2. To group applicants in accordance with the likelihood of their successful performance, and
3. To rank applicants, selecting those with the highest scores for employment.

It is important that the instrument used in the selection process meet certain standards(*6*):

1. The instrument should be copyrighted no earlier than 1991.
   - Two pieces of legislation that have directly impacted testing are the Civil Rights Act of 1991 and the Americans with Disabilities Act of 1990.
   - The provisions of both of these acts must have been considered in the construction of any psychometric instrument used in making business decisions involving people.
2. The instrument must have been designed for use in a selection process.
   - Validation is a major element of compliance.
   - That the instrument measures what it claims to measure must be demonstrable.
   - The instrument can demonstrate its validity under the same circumstances in which it is being used.
   - Many instruments that were originally validated for use in counseling and self-development cannot be validated as hiring tools.
3. The technical manual for the instrument must provide thorough documentation of
   - The development of the scales used.
   - The development of the norms.
   - The diversity of the population used in the studies. (A robust sample would include several thousand people, representing a mixture of appropriate ages, sexes, cultures, and races.)
   - The psychometric studies that generated the original norms should be revisited once every 3 years or so to allow the instrument to adjust to changes in demographics and social values and attitudes.

The ADA mentions in Section 1211(d) that a company "may make pre-employment inquiries into the ability of an applicant to perform job-related functions"(*7*). This clearly permits the use of validated assessment instruments such as job match assessments and honesty tests (if used properly).

USING JOB MATCH ASSESSMENTS WITH EXISTING EMPLOYEES

Have you ever worked with someone whose performance was not what you expected? Today, job match assessments can tell you why that happened and whether it can be changed. The accuracy of higher-generation assessment instruments has created extraordinary possibilities for analyzing and understanding the performance of existing employees.

Almost all managers or supervisors know who their best and worst employees are. What they generally do not know is why people hired by the same methods, doing the same job, and managed by the same person perform so differently. For centuries, businesses and organizations have relied on observation, opinion, and emotion to solve their people problems. At the same time, system solutions were based on objective data, quantified data, and common frame of reference. Modern assessment instruments can provide this same level of data about people.

The concept of the three cornerstones of job performance for selecting new employees is also essential to understanding the performance of existing employees. In the case of successful current employees, job attitude is a more precise terminology than organization match. Successful current employees typically have a can-do attitude and believe in the value of the contribution of each employee. They are positive and enthusiastic and are happy with their work place. Many factors affect this attitude, such as organizational leadership, work environment, and personal issues.

If job attitude is the only problem within an organization, motivational programs can work well toward improving performance. If, however, there is a more fundamental cause reducing performance, motivational programs can prove to be expensive and frustrating.

The second part of the puzzle of existing employees' performance is skills match. Well-constructed training programs may have a tremendously positive effect on skills match. The difficulty arises when training is viewed without consideration of job match. Job match, as described earlier, is the degree to which the employee has the cognitive abilities, interests, and measurable personality traits that are necessary to perform the job successfully. When job match is determined prior to training, the most effective training program is usually clear. The critical point is that unless job match is known, the best training is a hit-or-miss proposition: it can be frustrating for the employee and expensive for the organization.

Team Engineering Versus Team Building

Personality assessments have been used for team-building exercises since the first half of this century. Often four personality types are identified: dominant, influencing, stable, and compliant, or driver, expressive, amiable, and analytical. Other assessments may identify eight or nine types. All of these typing methodologies are based on behaviorism, or behavioral style theory, a concept that is no longer supported in mainstream psychology. Team-building exercises based on these four quadrants, however, can be often very productive. The concepts are simple and easily understood. The construct is valid and accurate. The exercise normally does a superb job of describing each type and

how each type relates or communicates with other types. The problem is that there is no accurate way for these instruments to sort people into types. It is unlikely that just four sizes fit all.

The most recent generations of assessment tools incorporate a total picture of cognitive abilities, interests, and personality. All of these factors play key roles in team interaction. More importantly, these newer instruments measure a range of discrete elements with considerable accuracy. This enables specific analysis of team fit. It also has the capability to deal with teams that are relatively homogenous or with work teams composed of specialized positions. The level of specificity possible is reflected in the designation of the process as *team engineering*.

Reorganization or Restructuring

The concept of job match is integral to any plan for reorganizing a work force. Without it, the outcome of the process becomes largely a matter of luck or hope. Job match assessments can be used to statistically analyze both the old system and the new configuration. The existing population of employees can then be compared to the new requirements of job match, and a strategic plan for transition can be developed. Some employees will fit easily into the new design, others will be phased in with training, and the ones that cannot make the change can be identified.

SUCCESSION PLANNING

Succession planning is basically a matter of an internal selection process. Job match assessments allow the analysis of an executive's career path relative to the various job matches that are available. Even when experience demands a period of time in a position of marginal benefit, that analysis enables a temporary adjustment of the expectations of performance during that period. This information can also be used to design individual training curriculum.

It is important to note that the numbers 1 through 10 make up the range of a scale. A person's holding any position(s) on the scale does not imply good or bad about that person. The numbers in the range are used to relate an individual's match to the requirements of a particular job. Everyone is a good match with some jobs and a bad match with others. In other words, accurate assessment tools do not judge a person good or bad; they only assess whether a person does or does not match the requirements of a particular job.

Please note that some of the words used to describe the person's personality characteristics don't necessarily mean what you and I usually think of when we use them. Psychologists have their own vocabulary.

Once you know the total person, you must be sure you know the job and its requirements. Then you must investigate the qualities a person needs to succeed in that job. You accomplish this by doing a study to determine what kind of person the job requires (organizational Match, skills match, and job match).

TABLE 2 Fifth-Generation Assessment Tool

ABILITIES

	1	2	3	4	5	6	7	8	9	10
General Ability										
Working with Numbers										
Working with Words										
Working with Shapes										

INTERESTS

	1	2	3	4	5	6	7	8	9	10
Working with People										
Working with Data										
Working with Things										

PERSONALITY

	1	2	3	4	5	6	7	8	9	10	
Diplomatic											Independent
Cooperative											Competitive
Submissive											Assertive
Spontaneous											Conscientious
Innovative											Conventional
Reactive											Organized
Introvert											Extrovert
Self-Sufficient											Group-Oriented
Reserved											Outgoing
Emotional											Stable
Restless											Poised
Excitable											Relaxed
Frank											Social Desirability

TABLE 3 Definition of Terms

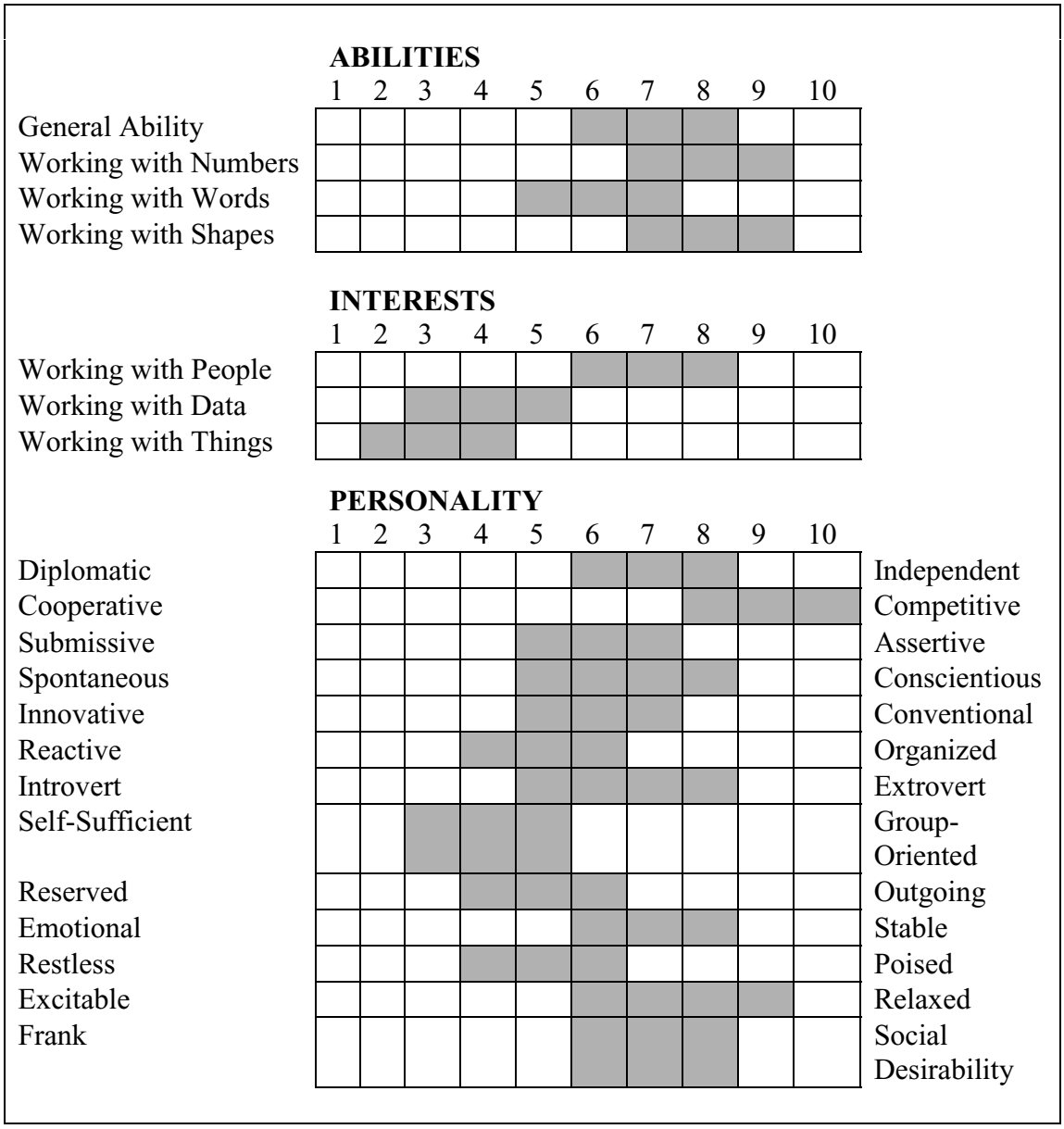
Diplomatic	Avoids conflicts and chooses to encourage others.
Independent	Single minded and determined to win.
Cooperative	Contributes to the work of the team.
Competitive	Plays to win.
Submissive	Avoids conflict and takes a diplomatic approach to disagreements.
Assertive	Outspoken, always trying to dominate others.
Spontaneous	Flexible and nontraditional.
Conscientious	Likes to work within a set of strict personal and traditional rules.
Innovative	Has a casual attitude toward rules.
Conventional	Always follows the rules.
Reactive	Reacts to events only when they arise.
Organized	Works well in a controlled, rational, well-planned environment.
Introvert	Prefers the company of a few good friends.
Extrovert	Happiest when at the center of attention.
Self-Sufficient	Content to work alone quietly for long periods of time.
Group-Oriented	Has a strong need for association and to be in the center of things.
Reserved	Stays in the background in social situations.
Outgoing	Likes meeting new people and doing exciting things.
Emotional	Suspicious, wary of the unexpected.
Stable	Accepts people and criticism at face value.
Restless	Generally upset and irritated about something.
Poised	Takes a rational approach to life.
Excitable	Has difficulty coping with high levels of pressure.
Relaxed	Can manage life's pressures.
Frank	Usually candid and frank.
Social Desirability	Has desire always to present self in best possible light because of strong desire for social acceptance.

Evaluating the top and bottom performers in a job classification is the best basis for performing the study. Think for a moment about a key department in your organization.

- Can you identify the top people in the department?
- Do you know the bottom people?
- Do you know why they are different?

Normally, you didn't hire some of the people to be top performers and others to be bottom performers. However, when a study is made of your top and bottom people, the characteristics that make your top performers different can be identified and made into a job match pattern for new hires or effective training programs for existing employees.

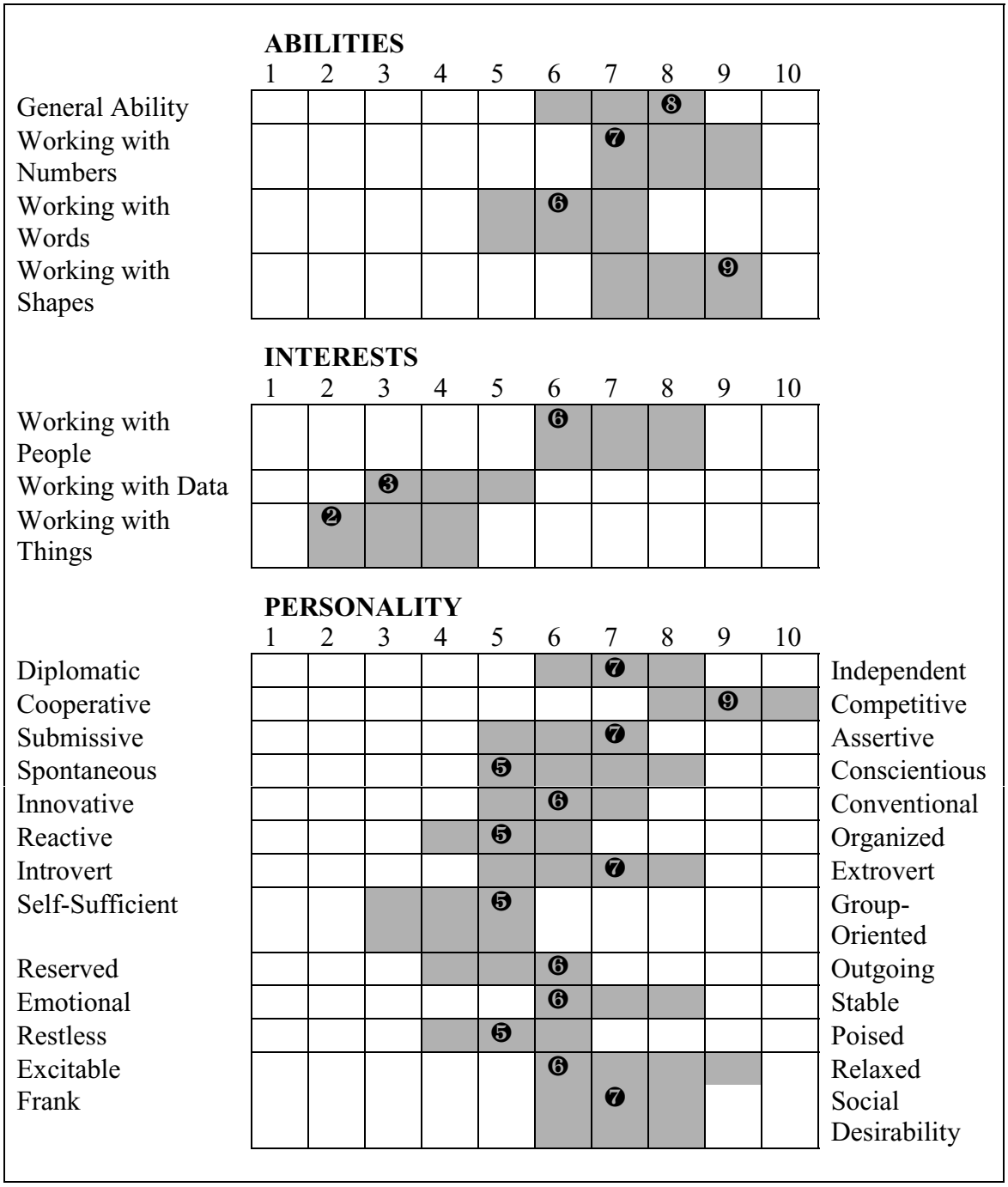
TABLE 4 Job Match Pattern



The job match patterns can be customized exclusively for your own organization—by job title and by department. A well-designed job match pattern can even take into account different management styles and expectations.

The shaded areas indicate the job match pattern for a particular job. Creating patterns is a major step forward for most organizations who do not have the job descriptions required by the Americans with Disabilities Act. These patterns can be customized for all the jobs in your organization, based on the qualities of your people who are already successful and the different management styles of your department heads.

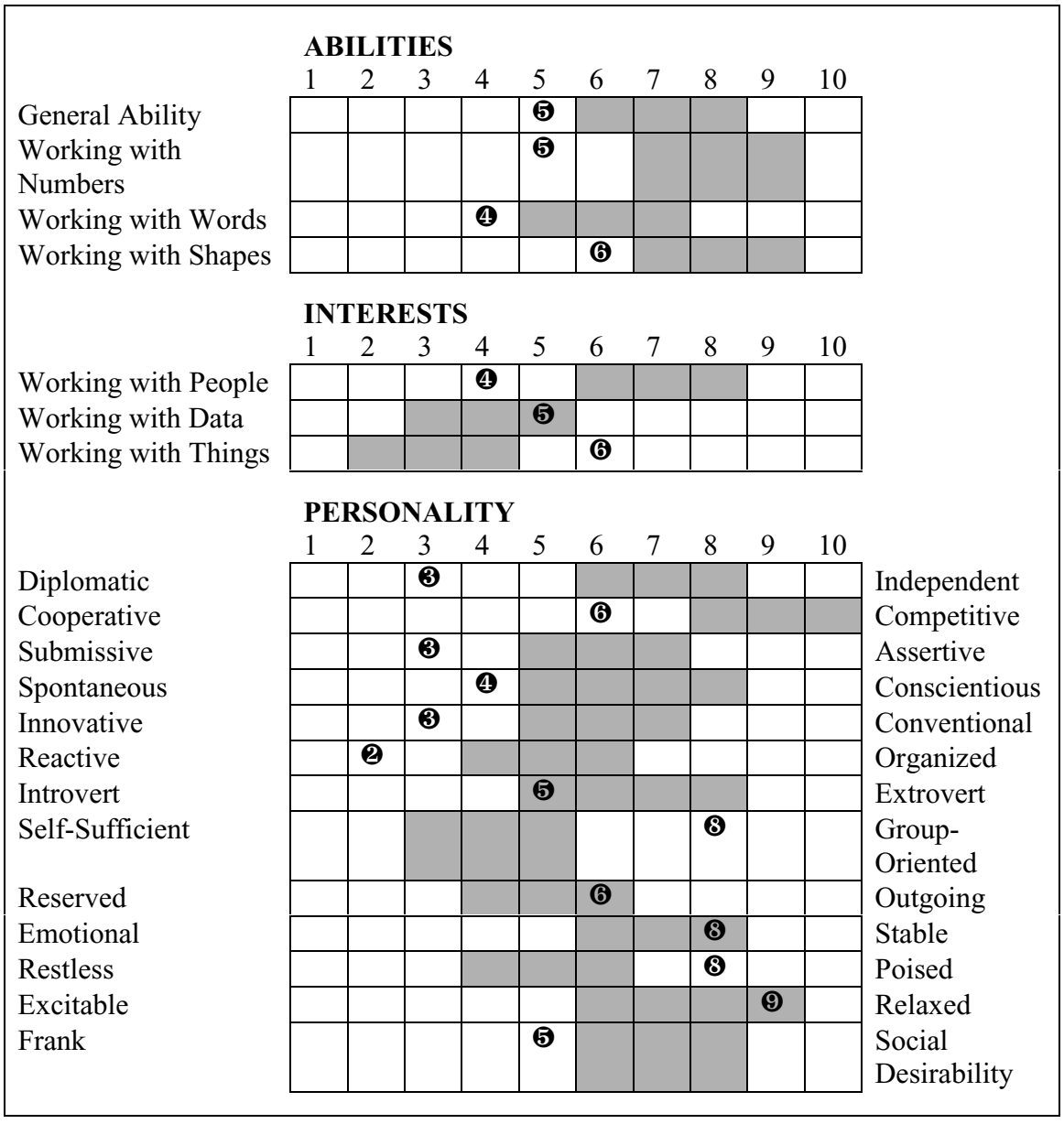
TABLE 5 Good Match, Candidate Compared to Job



The shaded areas are the job match pattern and the black-encircled numbers are the candidate's score. You can quickly see that all of the numbers are within the shaded areas, indicating a good match. You can tell at a glance if a particular job candidate is like your top performers. You can quickly tell if the candidate is the right match or a miss.

Every score doesn't have to fall into a shaded area in order for a candidate to be a good match. A candidate whose score matches 80 to 85 percent of the job requirements would be considered a good match. Candidates with scores that match 70 to 75 percent of the job requirements may also prove to be successful with properly structured coaching and training.

TABLE 6 Bad Match, Candidate Compared to Job



Again, the shaded areas are the job match pattern and the black-encircled numbers are the candidate's score. You can quickly see that several of the numbers are outside of the pattern, indicative of a bad match. Candidate scores matching less than 70 percent of the job requirements indicate a poor match.

To further validate the importance of matching people to jobs, the *Harvard Business Review* published results of a study involving more than 360,000 working people in 14 industries that had both high and low turnover rates. The study's objective was to examine the effectiveness of traditional hiring practices as a means of filling jobs with productive people. The study concluded: "It's not experience that counts, or college degrees or accepted factors; *success hinges on fit with the job*"(*8*).

TABLE 7 Comparison of Job Match or No Job Match and Effect on Turnover (*8*)

High-Turnover Industry *Sample Size: 13,102*

After 6 months	Percentage who quit or Were fired (%)
People with job match	24
People without job match	46

After 14 months	Percentage who quit or Were fired (%)
People with job match	28
People without job match	57

Low-Turnover Industry *Sample Size: 5,941*

After 6 months	Percentage who quit or Were fired (%)
People with job match	5
People without job match	25

After 14 months	Percentage who quit or Were fired (%)
People with job match	8
People without job match	34

Clearly, the *Harvard Business Review* study indicates that if you want to cut your turnover rates and their resultant costs, start matching people to the job. As J. W. Marriott of Marriott Hotels once wrote, "Put the right people in the right job. Train and motivate them, give them an opportunity for advancement, and your company will grow and prosper."

REFERENCES

1. Russell, C. *Right Person—Right Job: Guess or Know: The Breakthrough Technologies of Performance Information*. Johnson & James Press, Alpharetta, Georgia, 1996.
2. *Einstein Quotes*. Colorado Springs, Colorado, 1998.

3. Coates, D. E. *Soar With Your Strengths*. Delacorte Press, New York, 1992.
4. Hogan, J. *Employment Tests: History and User Considerations*. PRO-ED Press, Texas, 1990.
5. *Americans With Disabilities Act Handbook*. EEOC and U.S. Department of Justice. U.S. Government Printing Office Press, Washington, D.C., 1991.
6. Duston, R. L. *The Effects of the ADA on Employee Selection Procedures*. University Publications of America Press, 1992.
7. *Use of Integrity Tests for Pre-Employment Screening*. U.S. Congress. Office of Technology Assessment, U.S. Government Printing Office Press, Washington, D.C., 1990.
8. Greenberg, H. M., and J. Greenberg. Job Matching for Better Sales Performance. *Harvard Business Review,* Vol. 58, No. 5, Sept.-Oct. 1980, pp. 128−133.

By-Pass Filters:
Taking Your Fleet the Extra Mile

Donald S. Culpepper
Gulf Coast Filters, Inc.

There has been an industry-wide push over the last few years to extend oil drain intervals on fleet equipment. This industry demand is an effort to reduce downtime, reduce waste oil generation, and cut maintenance costs. Extended oil drain intervals can offer huge benefits for DOT fleets, providing that the extended program is structured to ensure that engine life is not compromised. The oil manufacturers have responded to this demand by developing new oils with improved additive packages to extend oil drain intervals. Many manufacturers advertise their new oil in many of the fleet maintenance magazines, with claims of extending oil drain intervals up to 40,000 miles. However, the question must be asked whether the use of these new oils in a "pour-in-and-go" program is the best approach to achieving satisfactory extended oil drain intervals.

This paper describes an approach to achieving effective and safe extended lube oil drain intervals. This approach has achieved extended equipment life with reductions in downtime, maintenance man-hours, waste oil generation, and costs. This approach utilizes ultra fine (UF) by-pass lube oil filters, an effective technology in use for over 20 years, along with a comprehensive monitoring process for tracking of wear and oil condition and detection of potential problems. This paper also addresses problems and hurdles encountered when extended oil drain programs are explored.

INTRODUCTION

The basic approach described in this paper utilizes standard petroleum lube oils, UF by-pass lube oil filters, portable oil quality analyzers, and laboratory oil analysis (see Figure 1). The standard American Petroleum Institute (API CG) rated petroleum-based lube oils are used in lieu of more expensive blended or full synthetic oils. There is no need for synthetics to achieve extended oil drains when UF by-pass filters are being used. However, certain fleets should look at other benefits, such as low pour points for cold weather applications. The UF by-pass lube oil filters are used to remove solid and moisture contamination from the lube oil. These filters, in conjunction with new make-up oil added at the time these filters are serviced, will keep the equipment running on clean oil, thereby reducing wear and eliminating the need for routine oil drains. Using a portable oil quality analyzer will allow maintenance personnel to test the quality and condition of lube oils and to monitor equipment condition in their own shops. By using this process, one can detect potential problems before unnecessary downtime occurs. In addition, complete laboratory used oil analysis is used to monitor wear rates and compile information on equipment for use in long-term trending analysis.

DISCUSSION

The majority of DOT fleets in the United States operate equipment with standard factory filtration and manage it with a standard factory-recommended P/M (preventive maintenance) program. Most equipment utilizes standard filtration in the form of factory full-flow filters only. There are a few cases in which the factory full-flow filters are coupled with by-pass filtration. The standard P/M program is the manufacturer's recommended routine oil and filter drain intervals. In some cases a complete laboratory used-oil analysis is used as a P/M tool. This type of P/M program is sufficient for normal equipment life. However, experience has shown that most highly successful fleets do not become successful by doing what is considered normal.

The recommended P/M program described in this paper, developed and proved over a 20-y period by Gulf Coast Filters, Inc., will move a fleet's preventive maintenance program toward a predictive maintenance program. The utilization of UF by-pass filters with this approach is a key factor. The by-pass filter performs the job of removing solid and moisture contamination to prevent additive depletion of the oil and reduces wear to the engine. Beyond extending the lube oil drain interval, this approach will

1. extend or eliminate routine oil drains, or both;
2. reduce wear within the equipment;
3. reduce equipment downtime;
4. reduce maintenance man-hours;
5. reduce waste oil generation; and
6. reduce costs.

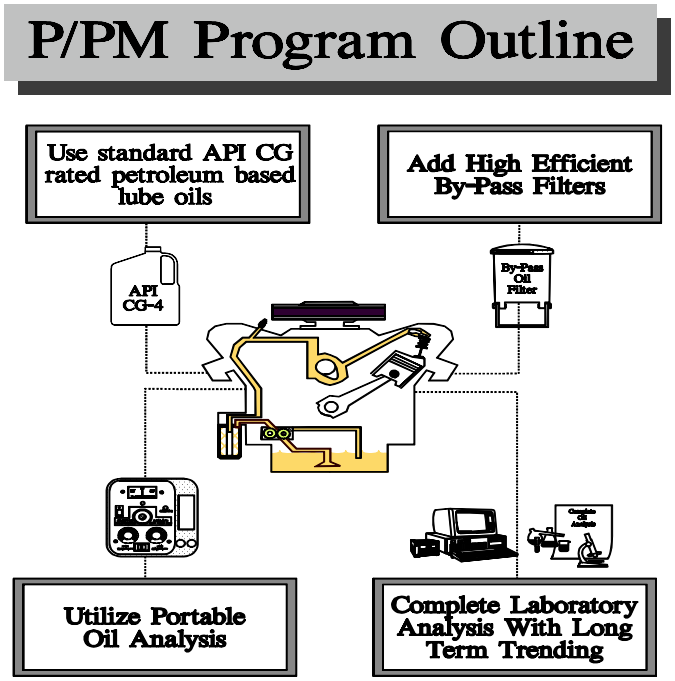


FIGURE 1 Basic approach using by-pass filters in P/M program.

Lube Oil Job Functions

There are several jobs that the lube oil is designed to perform: lubrication of moving parts, cooling, cleaning, corrosion control, and so forth. The oil companies work diligently to produce oils to meet engine manufacturers' ever-increasing requirements, creating better and better oils each year. Over the years, using vastly improved oils, the engine manufacturers have increased their recommended oil drain intervals for engines, but most fleets continue to drain oil on a routine basis. When most maintenance personnel are asked why oil must be changed, they usually answer in one of the following ways: "because it breaks down," or "because it wears out."

The concept that oil breaks down or wears out is not correct. The petroleum base of lube oil does not wear out, but rather it is the additives within the oil that become depleted due to the presence of contamination. Therefore, if one could remove these contaminants, the oil could be used for a longer period of time, but how long the decontaminated oil could be used is not known.

New Engines

The major contaminant produced in a diesel engine is soot. In recent years' changes in engine design to comply with higher Environmental Protection Agency (EPA) emission standards, engine manufacturers have fabricated engines that produce higher levels of soot in the oil. Therefore, contaminants that once were going up in smoke are remaining in the engine and winding up in the lube oil. These newer engines emit fewer contaminants through the exhaust; therefore, higher carbon soot levels are being detected within the engine. Several Society of Automotive Engineers (SAE) papers have shown how soot contributes to diesel engine wear (for example, SAE papers 810499, 852126, 881825, 881827, and 912344). One of these papers (912344) indicates that soot enters the lubricating oil at a rate of 0.0048 oz for every gallon of fuel burned. At 7 mpg, a truck will burn 1,786 gallons of fuel every 12,500 miles, with more than half a pound (8.57 oz) of soot entering the lubrication system.

The majority of soot particles generated within the engine are 10 microns or less. The standard full-flow filters will remove and control particles 15 microns and greater. Full-flow filters are designed to protect the engine from large particles that could damage vital parts. These filters must be porous enough to allow high flow rates of oil to the engine for lubrication of parts. The typical flow rate for a full-flow filter within a diesel engine is 15–20 quarts per minute. The filters are not designed to remove contaminants that are small in size.

Engine Oil Contaminants

The problem of soot contaminants in engines will increase in the years to come. EPA emission requirements for the year 2004 will force the diesel industry to deal with exhaust gas recirculation (EGR). In March 1998, at API's Lubricants Committee meeting in San Francisco, as reported in the May 1998 issue of *Lubes-n-Greases* magazine (*1*), a representative of Cummins Engine Company noted that "Diesel engine manufacturers face the prospect of having to reduce their drain interval recommendations significantly because of increasing levels of soot, caused by the need to introduce EGR."

In an effort to reduce nitrogen oxide (NO_x) emissions in the year 2004, it will be necessary to incorporate EGR for diesel engines. EGR exhaust is cooled and recirculated through the engine in order to reduce oxygen concentrations within the cylinder, thereby lowering flame temperature and nitrogen oxide (NO_x). Soot and fuel sulfur oxides are critical issues with EGR. In the opinion of the representative from Cummins, the only current way to handle increased levels of EGR soot is to remove it by changing the oil more frequently. He further noted that a dramatic decrease in oil change intervals to, say, around 10,000 miles would be needed. Instead of trying to solve this problem of higher soot levels by adding additional filtration, the engine manufacturers and oil companies are relying on those new oils to solve the problem—and if the oil companies cannot come up with new oils that can contend with EGR soot, the only option will be to shorten oil drain intervals. Is this the only option?

There is a very common-sense approach to the dilemma facing the engine and oil manufacturers. Soot is not a gas or liquid; it is solid particulate. A by-pass oil filter only filters about 10 percent of the oil each minute through a very dense element. It does not supply the engine with oil for the purpose of lubrication. Its sole purpose is to clean the oil. By-pass filters can control the higher levels of soot and other solid contaminants within today's engines, as well as into the future, without the need to go to a higher-tech oil. There are three basic types of contaminants that must be addressed: solid, moisture, and condition-caused contaminants.

Numerous tests and studies have shown that solid contaminants in the 1–15 micron range are responsible for the majority of normal wear within an engine. The standard factory full-flow filter does not control 1–15 micron particles, due its porous design required to supply engine parts with a high flow rate of oil. UF filtration, however, is capable of controlling solids in the 1–15 micron range.

Moisture within the lube oil causes viscosity to increase, VI polymer to decrease, and TBN to decrease, along with acid formation and accelerated oxidation and nitration. If left unchecked, moisture will contribute to accelerated wear, filter plugging, sludge formation, and corrosion of parts. Utilizing by-pass filters with absorbent filter media, such as cellulose or cotton, will remove suspended moisture from the lube oil.

There are three major condition-caused contaminants that are formed within the lube oil during normal use: oxidation, nitration, and acid. These contaminants are formed when solid contaminants and moisture are present and certain operating conditions exist within the engine.

Oxidation occurs when the hydrocarbon constituents of lube oil combine chemically with oxygen. Lube oil in engines will combine with available oxygen under certain conditions to form a wide variety of oxidation products. Many of these direct or primary oxidation products combine with other materials such as wear metals, solid contaminants, and moisture, to form second and third derivative products. As with most chemical reactions, oil oxidation is accelerated by heat and pressure. Effects of oxidation within the engine can be seen in the form of accelerated acid formation, corrosion, oil thickening, deposit formation, and accelerated wear. The presence of engine wear metals accelerates the oxidation process. Wear metals and other solids tend to hold heat, thereby increasing the lube oil temperature around the solid contaminants to accelerate the oxidation process. Combine this effect with the presence of moisture (H_2O) from normal condensation within the engine, and the oxidation process accelerates even faster.

Moisture within the lube oil offers a readily available source of oxygen to accelerate the oxidation process. Utilizing UF by-pass filters to remove solid and moisture contamination drastically reduces the oxidation process. Factor in fresh additives introduced by new oil added at the time of servicing by-pass filters and oxidation can be held in check.

The combustion chambers of engines provide one of the few environments where there is sufficient heat and pressure to break the atmospheric nitrogen molecule down to two atoms that can react with oxygen to form nitrogen oxide (NO_x). When nitrogen oxide products enter the lube oil through normal blow-by, they react with moisture present in the lube and become very acidic and rapidly accelerate the oxidation rate of the oil. Proper by-pass filters can control the effects of nitration in the same ways they control oxidation.

Acids are formed within the lube by several sources, two of which are oxidation and nitration. In almost all forms of fuel for internal combustion engines, trace amounts of sulfur are present. Sulfuric oxides are formed in the combustion chamber when sulfur molecules react with oxygen. These sulfur oxides then are blown past the rings and enter the oil. Here the sulfur oxides mix with moisture to form the highly corrosive sulfuric acid. It takes two components to make sulfuric acid: sulfur oxides and water. Proper UF by-pass filters remove the moisture from the lube and keep it chemically dry, thus controlling the formation of sulfuric acid.

WEAR REDUCTION WITH USE OF UF BY-PASS FILTERS

As the UF by-pass filter removes and controls contamination limits within the engine to extend oil drain intervals, another major benefit can be realized. With less contamination in the lubrication system, significant wear reduction is achieved. Consider these facts:

1. More than 80 percent of normal wear generated within an engine becomes contaminants that the factory full-flow filter allows to pass;
2. Ninety-eight percent of the solid contaminants generated within engines is below 10 microns in size; and
3. the factory full-flow filters are only effective in controlling particles 15 microns and larger (see Figure 2). A UF by-pass filter can be added to reduce normal wear and thereby extend the life of the equipment. If an engine runs on clean oil 100 percent of the time, the engine will last longer. With UF by-pass filters, wear can be reduced from 25 to 50 percent. In cases in which equipment is operating in adverse environmental conditions, such as dusty conditions, the use of UF by-pass filters can reduce wear up to 400 percent. The fact that UF by-pass filters drastically reduce wear has been well documented by SAE.

A factory full-flow filter is designed to remove large particles that could damage vital parts. The full-flow filter does little to reduce normal wear within the engine. The vast majority of solid contaminants generated within the engine are below 10 microns in size. As shown below, the full-flow filter is only capable of controlling 15-micron-and-up particles, allowing the smaller size contaminants to pass into the lube oil. Once introduced to the lubrication system, the oil has the job of suspending these tiny particles within the additive package. However, abrasive contaminants in the oil tend to grind

away at bearings, cams, and other engine parts, causing the normal wear. UF by-pass filters are capable of removing and controlling particles down to 1-micron size range. By using UF by-pass filtration, fleets can accomplish extended engine life.

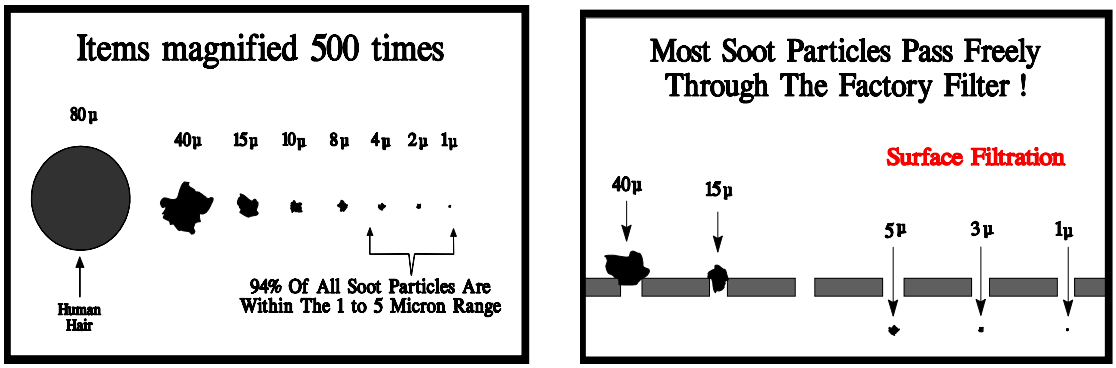


FIGURE 2 Filtration of soot particles.

FIELD RESULTS: EXTENDED OIL DRAIN PROGRAM

For many years numerous fleets have been utilizing UF by-pass filters and this type of P/M program. The level of oil drain extension depends on the goals to be achieved, as well as on the maintenance personnel's ability to carry out the P/M program needed to reach those goals. The following are three working examples of this program.

North Carolina Department of Transportation (NCDOT) used to change lube oil on its dump trucks at intervals of 5,000 miles. After a comprehensive test period using by-pass filters, NCDOT now changes the by-pass filter at 5,000 miles and performs a complete oil drain at 10,000 miles, doubling the oil drain interval. After successfully utilizing this program for over 2 years, NCDOT is now considering extending its oil drain further.

The North Carolina Ferries Division has more than doubled its diesel oil drain intervals. On small bore Cat engines, the oil drain intervals have been extended from 250 to 1,000 h. On big bore Cats, the oil drain intervals have been quadrupled, moving from 1,000 to 4,000 h.

Scott Paper Company was changing lube oil within its woodlands equipment each 100 h of operation, due to severe and dusty operating conditions. Scott elected to install by-pass lube oil filters and utilize the rest of the P/M program. The by-pass filters were serviced every 100 h in lieu of performing complete oil drains. The factory full-flow filters were changed every 500 h. The oil was sampled weekly with a portable oil analyzer and complete laboratory oil analysis was performed every 500 h. After 9 mo of testing, Scott elected to move the rest of its equipment to this program. Scott continued to service the by-pass filters as outlined above, but elected to perform a complete lube oil drain and filter change at 1,000 h even though lab analysis showed the oil to be in excellent condition.

Shell Oil has utilized by-pass filters in a P/M Program on its engines within the Gulf of Mexico for longer than 9years. After 2 years of rigorous testing and extending of

oil drains further and further, Shell Oil now only performs an oil drain when laboratory analysis deems it necessary. Some of its equipment has not had a routine oil drain in over 8 years. Shell personnel now service by-pass filters and sample the equipment with portable oil analysis units on a routine basis. Complete laboratory analysis is performed on a quarterly basis. Extending lube oil drains by the use of UF by-pass filters in a P/M program has streamlined Shell's lube oil maintenance operations, has drastically reduced downtime, and has led to dramatic savings on new oil purchases and disposal cost of waste oil. Also, Shell Oil has experienced wear reduction and extended engine life. Figure 3 illustrates the effects of using UF by-pass filters.

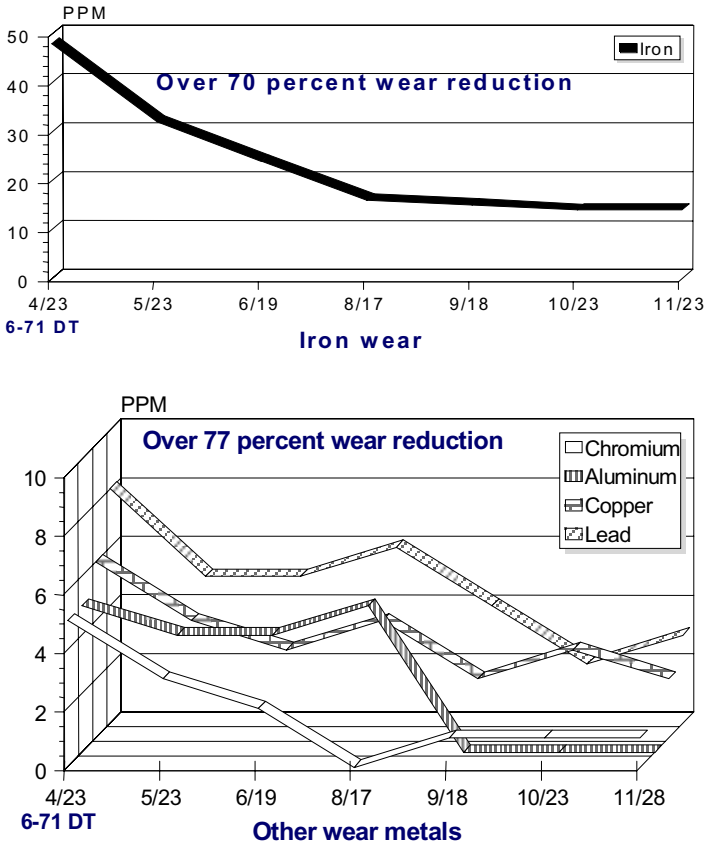


FIGURE 3 Shell Oil engine wear reduction.

PORTABLE OIL ANALYSIS

Knowing the condition of oil and equipment in the field is extremely beneficial to maintenance managers and maintenance personnel. A portable oil quality analyzer can deliver the above information. Most fleets that perform analysis on lubes utilize complete laboratory used-oil analysis. Primarily due to the cost of laboratory analysis, these tests are only performed on a routine basis—that is, monthly or at each oil drain interval. Laboratory oil analysis serves two basic functions. The first is to monitor the condition of the lube oil. Complete lab analysis is very effective in accomplishing this

goal. However, it is in the second function that lab analysis falls a little short: it does not give sufficient warning of possible failures such as coolant leaks and stress-related metal failures. Many fleets sample equipment lube oil on a routine basis, usually monthly or at the time of oil drain. While this is an interval sufficient to safely monitor the lube condition, many times this frequency is not sufficient for detection of engine problems. *Engine problems* is used here, not *engine failures*, because oil analysis is used to detect the problem before failure and downtime occur. An example of this situation is as follows. A company samples equipment oil on a monthly basis. On the first day of the month, a sample of the used oil is taken, and it is sent to the lab for analysis. On the second day, unbeknownst to the maintenance personnel and the oil lab, a coolant leak develops within the engine. The next scheduled time for a complete laboratory analysis sample to be taken is 29 days away. On the fifth of the month the operator receives the lab's results—which, of course, were taken before the problem occurred and therefore show everything to be OK and that the oil is suitable for further use. On the seventh, the operator notices that the oil is becoming cloudy. So much for detecting engine problems—the routine monthly sampling of the used oil has not been effective in achieving its goal of detecting engine problems.

The need is immense for a truly portable device that can be used on a more-frequent basis for determining the condition of the lube and equipment. A portable oil-quality analyzer is an accurate means of determining whether the oil and equipment are in normal or abnormal condition. The unit utilizes a dielectric testing method to test and determine the quality and condition of lube oil and equipment. Oil in its new state conducts very little electricity and is considered to be an insulator. However, as the new oil is subjected to use within equipment such as an internal combustion engine, it becomes contaminated, increasing its ability to conduct electricity. Oils used within engines collect contaminants such as copper, iron, other various wear metals, carbon from incomplete combustion, acids formed from oxidation, and more.

The oil-quality analyzer is electronically calibrated with new oil of the same type as is used within the engine. Then used oil of the same type from within the equipment is placed on the sensor, and the same electric charge is passed through the used oil. The contaminants within the used oil allow more current to flow, and this deviation from that of the new oil is shown on the meter, which gives a numerical increase to indicate the amount of contamination present. The increased current flow is in direct proportion to the amount of contamination in the used oil.

For over 20 years, Gulf Coast Filters conducted research to compare dielectric readings of portable oil quality analyzers to those of laboratory spectrographic analysis, particle counts, and other various laboratory analyses taken at the same time. During the course of the research, thousands of readings were taken with the portable oil analyzers on oil in many different types of equipment. Gulf Coast Filters was able to establish common parallels in the readings taken by the portable dielectric equipment and contamination levels indicated by complete laboratory analysis. This experience allowed the development of easy-to-use charts for almost every engine and equipment application. These charts allow the user to track equipment and to determine proper by-pass filter change intervals or, if the user is not using by-pass filters, complete lube oil drain intervals.

UTILIZING COMPLETE OIL ANALYSIS

Even though one is utilizing a portable oil-quality analyzer, one should utilize the benefits of complete laboratory used-oil analysis (see Figure 4). A spectrographic lab analysis can be used to confirm problems detected by a portable oil-analysis program. In addition, other lab samples should be periodically taken on equipment for the purpose of obtaining information for long-term trending of equipment condition. The interval at which lab samples should be taken should be determined by equipment runtime hours, severe-duty application, and many other factors. In many cases, only one routine sample per year may be necessary. The type of lab analysis should consist of full spectrographic analysis of 6 wear metals, silicon, and 13 additives. Also, physical tests should include viscosity, SAE grade, fuel soot, water, fuel dilution, antifreeze, and, last but not least, TBN (total base number). One should choose a reputable laboratory with numerous references and, once the lab is selected, stay with the same lab. It is not advisable to utilize two or three different labs for analysis on the fleet. Each laboratory's equipment can vary, causing the organization to receive different readings on the same equipment.

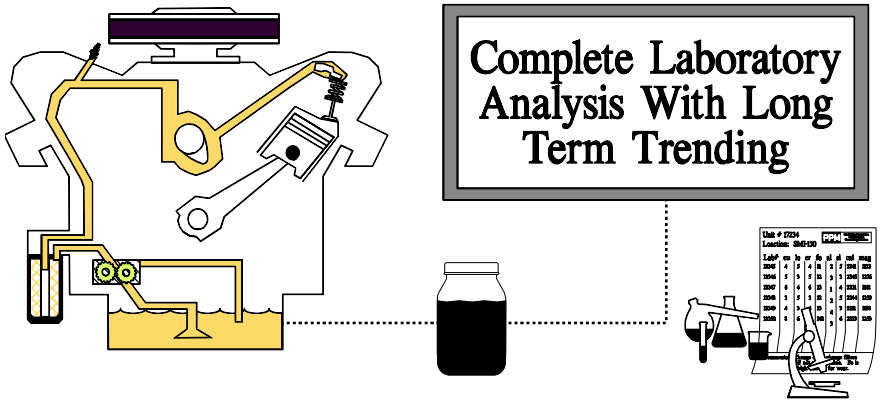


FIGURE 4 Complete laboratory analysis with long-term trending.

COST SAVINGS

The application of a UF by-pass filter program on equipment, such as DOT uses, from the small gasoline to large diesel engines has been shown to be cost effective. In most cases, return on investment is less than one year, when employing an indefinite oil drain interval. The following is an example of the application of this approach on a fleet of dump trucks (see Figure 5). Typically, a fleet of 100 dump trucks with an oil drain interval of once a month or 5,000 miles, using a cost of $50 for a routine monthly oil drain on each piece of equipment, including lube oil, factory full-flow filters, and labor would cost $60,000/year. This $60,000.00 maintains the lube oil and does not include complete laboratory oil analysis or any of its benefits, or disposal costs for the waste oil. With the use of UF by-pass filters, the monthly cost to maintain the lube oil in the same 100 trucks would be approximately $7.50 each, which includes a replacement filter element, oil, and labor. Also, each truck would require a maximum of two factory full-

flow filter changes in per year at a total cost of $18.50 for the filters, oil, and labor. After 150 laboratory used oil samples per year at a cost of $8.00 each are added, the total yearly expense on the same 100 trucks under this program would $12,050. This includes $9,000 for by-pass filters, $1,850 for two factory full-flow filter changes, and $1,200 for oil samples. To this, one must add the cost to retrofit a dump truck with a by-pass filter at $375 per truck, which includes parts and labor, or approximately $37,500.00 for the 100 trucks. The return on investment for this fleet would be less than 10 months or, if by mileage, less than 50,000 miles. Also, a yearly savings of $47,950.00 or 79 percent would be seen each year.

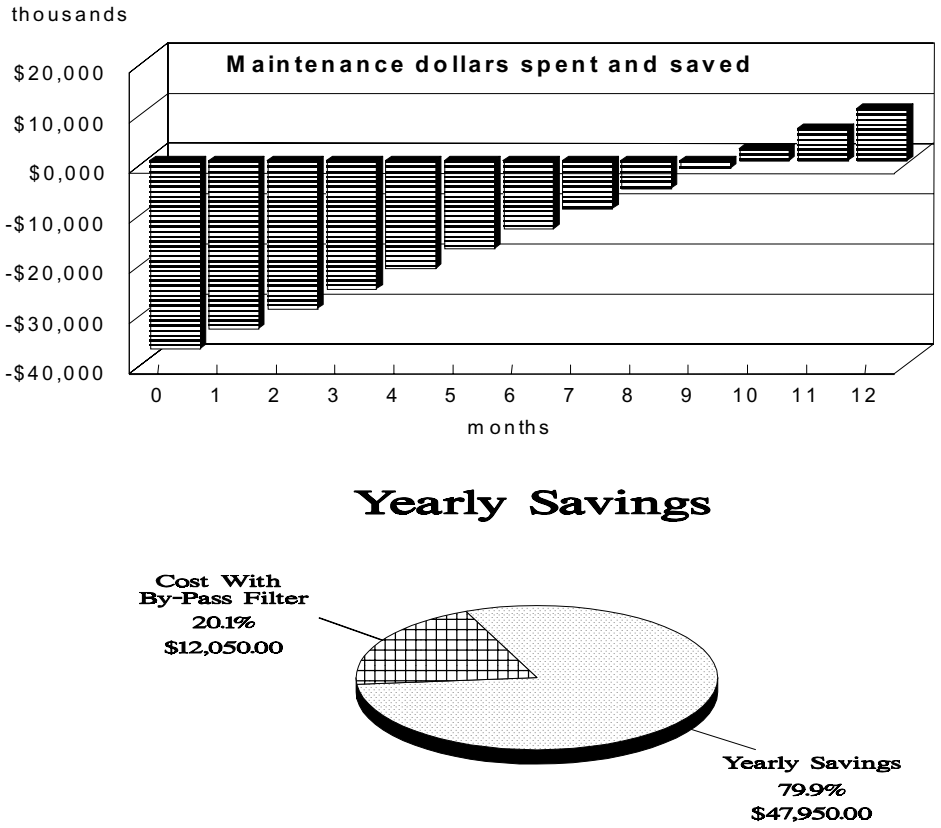


FIGURE 5 Return on investment and yearly savings for 100-dump-truck fleet.

SELECTING THE PROPER FILTRATION

An integral part of this process is the by-pass filter. There are many different types and brands of aftermarket filters and centrifugal equipment that boast claims of greatly extending or eliminating routine oil drains. Many of these claims are true; however, in some cases the truth has been stretched by marketing methods, claims based on in-house testing, and testimony from isolated customer bases. Also, many of these filters and centrifuges fall short of dealing with and controlling the amounts and types of contamination that need to be removed in order to achieve the goal of extending or

eliminating routine oil drains. In order to choose the right filter for the job, look for one that meets the following criteria and offers the following benefits:

1. Choose a by-pass filter that can control 1–5-micron–sized particles within the quantity that the engine or equipment is generating. There are several depth-type by-pass filters on the market that have the capability of controlling particles of this size. However, be sure to ask to see several particle counts taken on actual working engines or equipment similar to yours, and ask that those particle counts show ISO cleanliness levels.
2. Choose a filtration system that can remove moisture from the lube and keep the lubricant chemically dry at all times. This is critical. To control oxidation, nitration, acid formation, viscosity increases, and the other problems linked to moisture contamination, the filtration system must have the capability of removing moisture. Most depth-type by-pass filters with absorbent filter media such as cellulose (paper) or cotton fibers have this capability.
3. Choose a filtration system that has been proved within your field as legitimate in field test results, the worth of which can be confirmed by several users. Ask for field test results on equipment similar to your own. If the filter manufacturer cannot produce this type of information, look elsewhere.
4. Choose a filtration system that is backed by a company that can offer a proven P/M program to coexist with its product and your existing P/M program. There are many companies that specialize in selling filters; however, there are few filter companies that sell filters and specialize in predictive preventive maintenance. Also, select a company that has a significant number of satisfied users. Be sure to ask for a user list and call these users for their comments.
5. Choose a filtration system that is cost effective. Many factors need to be considered when you are determining the cost effectiveness of a filter. Look at the long-term savings from the filter. Look for the lowest-cost filter element that will achieve your goal. Filter elements achieving the same results can vary in cost, ranging from less than $2 to as much as $38 each. Also, consider durability of the filter housing, ease of installation, ease of service, and other critical points.

CONCLUSIONS

The use of UF by-pass filters and a comprehensive oil and equipment monitoring program has proven to greatly extend or eliminate routine oil drains. The benefits available to DOT fleets are significant, in that one can cut maintenance costs, extend the life of equipment, reduce equipment downtime, and reduce waste oil generation. UF by-pass filters in this type of program can work for you. There are a number of satisfied users of UF by-pass filters and this type of P/M program. Will UF by-pass filters and this program work on your equipment, with your personnel running the program? The only way to answer this question is obvious. DOT fleets should take a very close look at this type of program to enhance their maintenance operations. The benefits are rewarding.

REFERENCES

1. McFall, D. Diesel's Dirtiest Word. *Lubes'n'Greases Magazine*, Vol. 4, No. 5, May 1998, pp. 8–13.

Inspections of Aerial Equipment

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Aspen Aerials, Inc.

Inspections of aerial equipment are a requirement as set forth by the American Nations Standards Institute (ANSI). Owners of aerial equipment need to make themselves familiar with the standards that apply to their particular make and model of equipment.

The purpose of this paper is to generate a basic understanding of inspection procedures for aerial equipment and to help owners and users develop inspection procedures that will ensure the safety of personnel charged with handling equipment.

OPERATION SYSTEMS AND COMPONENTS

Operating systems allow the aerial equipment to be positioned at work locations not normally accessible by means of ladders or scaffolding. To fully appreciate the importance of a sound inspection program for aerial equipment it helps to understand how aerial equipment works. The normal system configuration of an aerial device includes

- Chassis,
- Stabilizers,
- Counterweight,
- Boom(s),
- Turntable(s),
- Platform,
- Hydraulic system,
- Limit system,
- Remote control system, and
- Safety shutdown system.

Chassis

The chassis is used for transportation of the unit to the desired work location.

Stabilizers

Stabilizers differ in design and location. On some overhead aerial equipment, outriggers are used to prevent the equipment from becoming unstable during operation. Axle locks (spring locks) are used in some applications to prevent instability. Most stabilizer systems are engaged using a hydraulic valve. However, there are some stabilizers that are moved manually.

Counterweight

Installing a counterweight to aerial equipment is another means of stabilizing the unit. The location of the counterweight is dictated by the weight and configuration of the boom(s).

Boom(s)

Booms are an important feature of aerial equipment. The boom(s) are generally operated by hydraulic cylinders located at the pivot areas of the device. On units designed for high-voltage power line maintenance, a portion of the boom(s) will be made with fiberglass. When certain manufacturing processes are applied, fiberglass will take on an insulating quality, termed *dielectric* within the industry.

Turntable(s)

Most aerial devices have at least one turntable, which is usually operated by a hydraulic orbit motor mounted on a gearbox.

Platform

The platform is generally mounted on the outermost portion of the boom system. Personnel operate the boom(s) by means of electrical controls such as joysticks or valve handles mounted on the platform. Platforms are usually made of fiberglass or aluminum. A manufacturer's decal located on the platform notes the maximum rated platform capacity that should not be exceeded.

Hydraulic System

The hydraulic system usually consists of a hydraulic pump, which is mounted to a power take off system on the truck transmission or directly coupled to a drive shaft connected to the truck engine. In some cases, a hydraulic pump is directly coupled to an auxiliary engine. There are several variations on this system, to provide fluid hydraulic pressure for the operation of the booms. The main valve is generally located at the base control station, usually at or near the main turntable. This valve controls the hydraulic pressure and flow to the hydraulic cylinders and orbit motors, which move the boom(s) and turntable(s). The main hydraulic valve is usually considered to be the primary control point. Another feature of the hydraulic system is the override device, which allows operation of the boom(s) should the electrical system fail. Aerial equipment that allows the booms to travel overhead may incorporate a manual let down system (valve), which allows the booms to be lowered if the hydraulic system fails.

Limit System

Stability of some aerial equipment is controlled through a combination of electrical limit switches and the hydraulic system. If the booms are being moved near a position that could create an unstable condition, a limit switch is tripped and the hydraulic flow is shut

off for that function and the booms cannot be moved into a position that would allow the equipment to become unstable. In most cases, operation of the unit can continue if the function that was being operated when the unit shut down is reversed.

Remote Control System

The remote control system is located at the platform and is one of two varieties:

Electrical

Electrical control handles (some times called joysticks) may be used to control the functions of the unit from the platform. The sticks transmit an electrical signal to electrical solenoids mounted on the main control valve. These control sticks are usually proportional and allow the operator to vary the amount of deflection applied to the control handle in order to control boom movement speed.

Another version of this system is the use of toggle switches. Toggle switches are not proportional; however, some valve manufacturers have designed valves to work with toggle switches. These valves meter the hydraulic flow and are sometimes referred to as soft-touch valves.

Hydraulic

On some aerial equipment, a hydraulic valve with handles may be mounted on the platform to provide operational control of the boom(s). This type of system is commonly referred to as a full hydraulic system.

Safety Shutdown System

Safety shutdown systems are a very important feature of modern aerial equipment. Shutdown switches are usually located inside of the truck cab, main control valve, and platform. Location of these switches depends on what type of work the equipment is performing. For instance, in a mobile operation such as inspection of bridges, the booms may be deployed and the driver of the truck may not be able to see the entire length of the booms. The platform operator may shut down the truck to prevent the booms from hitting a portion of the bridge structure.

TYPES OF INSPECTIONS

There are four generally accepted types of inspections that are performed on aerial equipment:

- Daily Inspections,
- Vehicle Inspections,
- Frequent Inspections, and
- Annual Inspections.

Daily Inspections

The daily inspection is normally performed by the driver or the operator (or sometimes both) of the equipment. Before use each day or at the beginning of each shift, the mobile unit shall be given a visual inspection and functional test. A daily inspection checklist must be followed when performing this inspection. The manufacturer of the aerial device is required to provide the owner/user with a daily inspection checklist. While use of the checklist is required, keeping a record of the daily inspection may not be required. It is important to check with local government agencies to determine what standards apply to your equipment.

Vehicle Inspections

Most aerial equipment is mounted on a truck chassis. There are specific regulations that apply to trucks and truck inspections. It is important to have the truck inspected in accordance with these regulations.

Frequent Inspections

Frequent inspections and tests shall be conducted on a mobile unit

- When it has been in service for three months or up to 200 hours, whichever comes first.
- Prior to operation after the unit has been out of service for a period longer than three months.

The frequent inspection shall be made by a person qualified as a mechanic on the specific make and model of unit. The inspection shall include all items specified by the manufacturer for a frequent inspection. The mechanic must follow a frequent inspection checklist when performing this inspection. Written records of frequent inspections shall be retained for a minimum of three years. Records shall include the date of the inspection, the name and signature of the person(s) accomplishing the inspection, description of any deficiencies found, and corrective action accomplished, including the date and the identity and signature(s) of the person(s) performing any required repairs.

Annual Inspections

Twelve (12) months from the date of the prior annual inspection—or not to exceed 1,000 hours of operation beyond the prior annual inspection, whichever occurs first—an annual inspection shall be performed. Inspections shall be performed by one or more person(s) qualified as a mechanic on this specific make and model of unit. The inspection shall include all items specified by the manufacturer for the annual inspection. Prior to the operation, all malfunctions and problems identified shall be corrected and further inspection, if necessary, shall be accomplished. A written record of the annual inspection shall be retained for as long as the unit is owned (lifetime). The record shall include the name and signature of the person(s) accomplishing the inspection, a description of any

deficiencies found, and any corrective action accomplished, including the date and the identity and signature of the person(s) performing any required repairs.

QUALIFICATION OF ANNUAL INSPECTION PROVIDER: IMPORTANT CONSIDERATIONS

Goal of Inspection

If the right inspection firm is employed and a complete inspection performed, and the inspection report is concise, the report will be an important tool in properly maintaining the aerial equipment. Remember that the safety of the people who operate the equipment is the most important aspect of the inspection.

Qualification of Inspectors

Has the inspector been trained on your make and model of aerial equipment? Will the inspector know how the safety system is designed to operate?

Resources

Will the inspector have the resources necessary in order to properly rate the serviceability of your aerial equipment? Access to design information such as electrical and hydraulic schematics is important.

Operational Testing

Many testing firms can perform a structural inspection; however, their personnel may not understand how to operate the equipment and may not be capable of diagnosing operational problems.

Summary

The safety of the personnel who operate aerial equipment depends on proper safety inspections. Thorough inspections have important side benefits: they protect our investment.

Daily Inspection Form

The following pages contain a daily inspection checklist for Aspen Aerials or Reach All Underbridge Units.

ASPEN AERIALS OR REACH ALL UNDERBRIDGE UNIT
DAILY INSPECTION FORM

INSPECTION DATE:

INSPECTION PERFORMED BY:

COMMENTS:

MAIN ENGINE COMPARTMENT:	**OK**	**COMMENT**
Engine oil:		
Coolant:		
Washer fluid:		
Power Steering fluid:		
Transmission fluid:		
PTO and hydraulic pump:		
Drive belts:		

CAB INSPECTION:	**OK**	**COMMENT**
Hour meter/odometer reading:		
Decals:		
Air pressure:		
Oil pressure:		
12-volt charging system:		
Braking system:		
Unit power light and switch:		
PTO indicator light and system:		
Two speed system:		
Axle lock lights:		
Strobe lights:		
Start/stop system (transmission in neutral):		
Tag axle system and pressure (if installed):		
Intercom system:		
Lights: 4 ways, head, turn, tail:		
Fuel level:		

- Start the truck engine, engage the PTO, set the engine to the correct rpm setting, and turn on all systems for the walk around inspection.
- Make sure the parking brake is engaged.

***WALKAROUND INSPECTION* (proceed around the unit in a clockwise direction):**	**OK**	**COMMENT**
Lights: 4 ways, head, turn, tail:		
Strobes, beacons, or sign board:		
Transmission and axles:		
Tires: front and rear:		
Axle locks (front/rear):		
Axle lock switches (front/rear):		
Hydraulic pump and hoses:		
Electrical switches and cables:		
Air hoses, outlets:		
Body boxes:		
Ladders and rails:		
Chassis suspension (front/rear):		
Counterweights and switches:		

AIR COMPRESSOR:	**OK**	**COMMENT**
Operational test:		
Air system hoses and valves:		
Electrical switches and cables:		
Gauges:		

GENERATOR:	**OK**	**COMMENT**
Operational test:		
Electrical wires and connections:		
Circuit breakers and outlets:		
Instrument panel and meters:		

HYDRAULIC TANK AND OIL COOLER:	**OK**	**COMMENT**
Oil level and gauge:		
Filter and gauge:		
Structure:		
Hydraulic hoses:		
Electrical switches and cables:		

AUXILIARY ENGINE:	**OK**	**COMMENT**	**Hour meter:**
Fuel filter, oil level, and oil press:			
Coolant:			
Switches, wires, connections:			
Hydraulic pump and hoses:			

- Preheat and start auxiliary engine. Listen for unusual noises, and check engine oil pressure, charging rate.
- Shut down auxiliary engine: auxiliary engine will be started again during the operations check.

COMPONENT CHECKLIST:

***See component checklist explanations:**	T-1	B-1	T-2	B-2	B-3	CATRAC B-3 TELE	B-4	PLATFORM
Cylinder								
Cylinder anchor								
Structure								
Hydraulic lines and fittings								
Electrical cables								
Pivot pin								
Rotations: gear, bearing, gearbox, brake, motor								
Limit switches								
Pressure filter								
Hydraulic valves; Unit, axle lock, dump								
Leveling rods								
Boom/platform rests								
Boom/platform tie-down								
Decals								
Platform heaters								
Outlets: 12 volt, 110 volt								
Air hose outlet								
Platform controls								
Leveling system								

(Shaded boxes do not apply to that area of the unit.)

COMPONENT CHECK LIST EXPLANATIONS:	
COMPONENT:	**WHAT TO LOOK FOR:**
Cylinder	leaks, scoring, rust pitting, cracks at pivot points
Cylinder anchor	visible cracks or damage, rusting
Structure	visible cracks or damage, rusting
Hydraulic lines and fittings	oil leaks, chafing, kinks, abrasions
Electrical cables	loose or broken wires and connections, chafing, abrasions
Pivot pin	visible cracks or damage, rusting
Rotation: gear, bearing, gearbox, brake, motor (T-1 and T-2)	wear, damage, oil leaks, broken bolts
Limit switches	bent switch arms, loose wire connections, LED functions
Pressure filter	oil leaks; check indicator gauge
Hydraulic valves; unit, axle lock, dump	free movement of the handles, return to neutral position when released; oil leaks; wiring connections secure
Leveling rods	cracks at pivot points, damage to rods
Boom and platform rests	nylon wear pad secure, cracks, damage to structure
Boom tie-down device	damage to nylon strap or ratchet
Decals	unreadable, missing or damaged decals
Platform heaters	broken switches or wires, secured to platform
Outlets: 12 volt, 110 volt	damaged or broken wires, secured to platform, broken covers
Air hose outlet	damage to hoses, coupling, regulator, and gauge
Platform controls	proper operation of all functions, damage to components
Leveling system	hydraulic line; wire or switch; secured to the platform

OPERATIONS CHECK AND HOLDING VALVE TEST:

The truck should still be running with the PTO engaged.

1. Remove the boom/platform tie-down device(s).
2. Engage axle locks and counterweight (*red* axle lock engaged indicator light).
3. Place the unit/axle lock selector valve in the "UNIT" position (PULL OUT).
4. Close B-2 and B-3. If you don't close B-2 and B-3, these booms may open when you raise B-1.
5. Raise B-1, *one foot* above the boom rests.
6. Lower the platform rests to the deck.
7. Lower B-4 approximately 45 degrees (if installed).
8. Place the unit/axle lock selector valve in the "AXLE LOCK" position (PUSH IN).
9. Now, perform the holding valve test. Watch for drift.
   - Operate B-1 to the "DOWN" position for 5 seconds.*
   - Operate B-2 to the "OPEN" position for 5 seconds.*
   - Operate B-3 to the "OPEN" position for 5 seconds.*
   - Operate B-4 to the "DOWN" position for 5 seconds.*
10. Test the hydraulic air compressor and generator (shut them down when test completed).
11. Test the T-1 intercom.
12. Raise the platform rests and lock them into place.
13. Test the truck engine start/stop system at the platform (red button). Leave truck engine off.
14. Test the platform intercom.
15. Start the auxiliary engine.
16. Use the auxiliary engine to stow the unit; this will test the auxiliary engine.
17. Place the unit/axle lock selector valve in the "UNIT" position (PULL OUT).
18. Raise B-4 (if installed).
19. Lower B-1 tightly into the rests (about 900 psi on the hydraulic gauge at T-1).
20. Place the unit/axle lock selector valve in the "AXLE LOCK" position (PUSH IN).
21. Disengage the axle locks and counterweight (*green* axle lock disengaged indicator light).
22. Install the boom / platform tie-down device.
23. Shut down the auxiliary engine.

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* If any one of the booms moves (drifts) during the holding valve test, perform the test again in order to verify which boom is drifting. The problem holding valve(s) must be replaced before the unit is put into service.

Remanufacture: An Alternative to Rising Equipment Replacement Costs

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The cost of new replacement equipment and vehicles is a significant portion of the annual budget of most transportation authorities, municipalities, and fleet operators. An additional large expenditure of this budget is the ongoing maintenance costs of aging fleets of equipment/vehicles that are not scheduled for new replacement due to budget constraints or extended equipment life cycles. An additional complication to this scenario is the extended delivery times of new replacement equipment. A solution to this continuing and escalating problem is the use of a sophisticated outsourced remanufacturing program.

This paper reviews the increasing problems that high-priced, complex new equipment has with escalation of maintenance costs and presents a viable solution. This solution, remanufacturing, has been used successfully for approximately 20 years. This proven solution has not been widely employed by the transportation authorities, state fleets, and public works throughout the nation.

INTRODUCTION

The primary missions of all of the transportation authorities, state fleets, and municipal and public works sectors do not include maintenance, repair, and procurement of equipment and vehicles. The primary missions of these entities are the services that each particular authority provides. Unfortunately, the equipment that is utilized to provide these services consumes a large amount of financial, administrative, and labor assets. The efficiency of these authorities can be greatly enhanced if use of these assets (financial, administrative, and labor) is reduced to the lowest possible level. This would allow the authorities to use the majority of their assets for the primary mission of providing services rather than for insuring the availability of equipment and vehicles. Accomplishing more while using fewer assets is exactly what the U.S. Navy and the Department of Defense have done over the last 20 years. The proven concept of remanufacturing has helped the U.S. Navy save millions of dollars and has reduced maintenance costs and efforts to minimal levels. The remanufacturing concept allows for a vehicle or equipment item to be renewed with full warranty for a percentage of new acquisition costs. During this process of remanufacturing, upgrades and enhancements are added to the unit. In many cases, customization to enhance performance of the equipment takes place, which allows the unit to perform more effectively. An additional feature of the remanufacturing process is rapid turnaround of these vehicles and equipment. This turnaround time is becoming important, what with the extended delivery time of new equipment fleets. When implementation of the program occurs, a monthly schedule of product deliveries takes place, which ensures a constant flow of the disused vehicles and equipment back into service after remanufacture. Special attention is given to areas such as corrosion prevention, load capacity, and enhanced hydraulics.

A remanufacturing program is extremely cost effective for larger, more expensive vehicles and equipment. In some cases the large equipment items can be remanufactured for 45 to 50 percent of new acquisition costs. Quantities of lower-priced units also can offer substantial savings due to the numbers involved. In those cases, the smaller, less expensive units can be remanufactured for 55 to 65 percent of new acquisition costs. The following information will focus on the details of the process, and the added benefits and cost savings that can result.

REMANUFACTURING PROCESS DETAILS

A proper remanufacturing program renews the life cycle of the vehicle or equipment. The procedure begins with inspection of the remanufacture candidate. This is accomplished for the purpose of determining visual structural damage, if any, as well as any missing components. A record is kept for future reference and is categorized by vehicle serial number and tracking number. The process then begins, with a complete teardown to the lowest component of the equipment or vehicle. This results in the removal of all components, down to the basic frame structure. After complete disassembly, paint and corrosion are removed from the components by one of several methods, which would include sand blast, glass bead, chemical strip, or physical removal. This allows the metal components to start from a clean white metal condition, since all coatings and corrosion are removed. This process also allows for full inspection of all areas. At this point, all subassemblies are fully disassembled to the lowest component. Examples include complete cylinder disassembly and inspection, which will show any internal deficiencies or wear, and differential teardown, with all gears, components, and housings inspected. If non-conformities exist, the items are brought back to the original size requirements or replaced. Items are not merely disassembled and reassembled, but they are also inspected and remanufactured to ensure that all dimensions and configurations, as well as structural soundness, are brought back to the original specifications and standards. This process is accomplished on all components, including the main structural items such as main frames, chassis, and so forth.

As the remanufacturing process continues, a critical area of inspection and correction is performed, involving intense examination and repair of all welded areas. Welds are visually inspected and, if found defective, are completely removed and rewelded. In critical areas where structures are weakened, Non-Destructive Testing (NDT) by either magnetic particle or penetrant inspection is utilized for detection of cracks or defects. This allows for any hidden defects to be detected and corrected. All welding must be performed by certified welding operators in accordance with ASTM Specifications for compatibility and form.

At this time, the establishment of a 100-percent replacement list is compiled. Each vehicle/unit will have a unique replacement list made, but the general areas of this list are as follows: rubber hoses (hydraulic, fuel, vapor), rubber bushings, hydraulic packing (all types), bushings/bearings, oil and grease seals, electrical wiring, cables and small electrical components, most gauges, most hardware items, shock absorbers, brakes, and most non-electrical cables. This unique system has proved over time that the mandatory replacement of these items ensures a renewed vehicle/unit, which begins a new life cycle and a full-life extension (zero time).

All hydraulic components (pumps, valves, cylinders, and so forth) are chrome plated as required; reassembled completely, utilizing new packing; recalibrated; and performance proof tested to the correct working hydraulic pressure. At this stage all of the components and structural items will have been remanufactured and the painting and corrosive protection accomplished. Since all components and structures are in a white metal state, protective coatings can be applied as if the items were new. All metal components and structures are primed with highly-corrosion-resisting primer and finished with a variety of optional paint coatings (enamel, epoxy, polyurethane, fluorinated polyurethane [FPU]). The components—such as hydraulics, engines, transmissions, differentials, and so forth—have now been remanufactured and function-tested, and are ready for reassembly. The vehicle/unit is completely reassembled in accordance with manuals and work instructions to ensure conformity, reliability, supportability, and maintainability in fleet use. Complete reassembly now occurs, utilizing various hold points for critical inspection areas. Upon this approved and completed reassembly, the vehicle/unit experiences an extensive function and weight certification test procedure, including all phases of simulated and actual use. Only after strenuous and satisfactory on-site testing and inspection will the customer be notified for inspection. The units will then be delivered to the customer at the designated delivery point.

UPGRADES AND RETROFIT

In addition to the complete remanufacture of aged and disused vehicles and equipment, upgrades can be added to these units. Upgrades include engine conversions such as gasoline to diesel, as well as the environmentally popular conversions from diesel or gasoline to compressed natural gas (CNG). Transmission upgrades, air conditioning, and a zero-maintenance remote lubrication system controlled by a small onboard computer are also accomplished for the purpose of upgrading existing vehicles and equipment.

Units such as tow vehicles can have increased capacity added during the remanufacturing process. This allows some existing vehicles/equipment items to do more than the original units were able to do. These upgrades and retrofits are accomplished at minimum cost because of the fact that the units are in completely torn-down state and require little additional labor. Upgrading can now customize the units, in addition to renewing them for a full service life extension.

SUMMARY

Properly utilized, remanufacture programs can allow transportation authorities, municipalities, and fleets to save substantial dollars over new procurement, enabling them to have equipment or vehicles that are low maintenance, 100-percent available, and upgraded to support their primary mission. The turnaround times for the program items can be as short as 45 to 90 days after full implementation of the program. A strictly controlled remanufacturing process, if diligently pursued and utilized, will result in the same type of savings for transportation vehicles and equipment as the United States Department of Defense has seen.

Report on the 1997–1998 Regional State Highway/DOT Equipment Managers' Conferences

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Regional Equipment Managers' Conferences are typically held annually in four geographic regions throughout the United States—Northeastern, Midwestern, Southeastern, and Western. Member states within each of the four regions take turns hosting the conference in order to spread out the responsibility and keep the meetings from becoming a burden on any one state. Most states find the conference very beneficial. The conference gives them a forum for exchanging and sharing ideas as well as for seeking possible solutions to concerns or problems in the equipment arena. Some states are even exploring innovative ideas like cooperative purchasing agreements in order to take advantage of quantity and quality purchases. One of the primary benefits of the conference is that it allows member states to develop contacts throughout their region. This allows the participants to make and foster business relationships with each other that will continue to benefit them throughout the years.

The conferences usually last two to three days and have formal agendas that are prepared in advance. This allows participants the time to research answers to questions from other member states. Tours of local equipment-related vendors are often arranged. Advertising is not permitted at the meetings, and subsequently, most groups do not allow vendors to attend or give sales presentations. However, vendors may be invited to give brief presentations of a generic nature. This keeps the conferences from becoming commercial and negates the perception of favoritism.

Three of the four regions—Western, Midwestern, and Southeastern—have been meeting regularly. The Northeastern region has struggled to meet on an annual basis. The TRB Committee A3C08, chaired by John Burns, Jr., encourages and supports the continuation of all regional conferences.

NORTHEASTERN REGIONAL CONFERENCE

The Northeastern Regional Group is comprised of 11 states:

Maine
New Hampshire
Vermont
New York
Pennsylvania
Delaware
New Jersey
Connecticut
Massachusetts
Rhode Island
Maryland

There was no 1997 Northeastern regional conference. Delaware was unable to hold the meeting due to insufficient staffing. The host state for the 1998 regional conference has yet to be selected.

MIDWESTERN REGIONAL CONFERENCE

The Midwestern Group is comprised of 13 states:

North Dakota
South Dakota
Nebraska
Kansas
Missouri
Iowa
Oklahoma
Minnesota
Wisconsin
Illinois
Indiana
Michigan
Ohio

The 9th Midwestern Regional Conference was held August 4–6, 1997, in Lawrence, Kansas, and hosted by the Kansas DOT. Some of the topics presented/discussed included

Iowa Concept Vehicle
Anti-Icing Equipment/Procedures
Equipment Management Systems
Life Cycle Costing Experiences
Purchasing Procedures
Equipment Operator Training
Alternative Fueled Vehicle
Equipment Services Outsourcing
Strobe Light Policy
Equipment Fueling
In-House Warranty Work
Equipment Leases

The group took a field trip to the Goodyear Tire Plant in Topeka to observe tires being made.

The 1998 conference was hosted by Columbia County Highway and Transportation in Madison, Wisconsin, July 27–29. The group took a trip to visit the Monroe Equipment Plant in Monroe, Wisconsin. Some of the topics presented/discussed included

Salt Brine Systems
GPS in Vehicles
Anti-icing
Alternative Fuel Vehicles
Electronic Engine
Service Intervals
Shop Personnel
Liquid Asphalt Injection Patching
New Technology

The 1999 conference is scheduled to be held in Indiana.

SOUTHEASTERN REGIONAL CONFERENCE

The Southeastern Regional Group is comprised of 13 states:

Texas
Arkansas
Louisiana
Mississippi
Alabama
Tennessee
North Carolina
Georgia
Florida
South Carolina
Kentucky
Virginia
West Virginia

The 10th Southeastern Regional Conference was hosted by Florida DOT at the Holiday Sunspree Resort in Panama City Beach, April 21–24, 1997. Some of the topics presented/discussed included

11th TRB Equipment Management Workshop
Under-Utilized Equipment
Tire Life
Purchase/Buy-Back
Equipment Disposal
Innovative Initiatives in Inventory Control
Trailer Loading Criteria and Training
Brush Cutter Use
Equipment Cost Comparison
Alternative Fuel Vehicles
Herbicide Spray Equipment
Motor Graders
Tag-Along Trailers
Off-Road Equipment Emissions

The group had several commercial vendors give presentations regarding product changes and on what is new in their business. The 1998 conference was hosted by Georgia DOT at Stone Mountain Park in Atlanta, May 4–7, 1998. Of the 13 states, 12 attended. Some of the topics presented/discussed included

Alternate Fueled Vehicles
Parts Contracts and Manuals
Update on Ford Truck Operations
Truck Photo Comparisons
Arrow Boards and Running Lights
Re-engineering the Purchasing Process
Fuel Treatment System
What's New at New Holland
Fleet Cross System
Fleet Pay Comparisons
Multiple Award Contracts
Mower Safety

The 1999 conference is scheduled to be hosted by the Texas DOT in Austin.

WESTERN REGIONAL CONFERENCE

The Western Regional Group is comprised of 13 states:

Alaska
Washington
Oregon
California
Hawaii
Arizona
New Mexico
Nevada
Utah
Colorado
Idaho
Wyoming
Montana

The 28th Western Regional Conference was hosted by Idaho DOT at Templin's Resort Hotel in Post Falls, August 19–21, 1997.

Some of the topics presented/discussed included

Equipment Purchasing and Disposal
Joint (Multi-State) Purchasing Options
Life Cycle Analysis
Equipment Management Systems
Year 2000 Concerns (Y2K)
Equipment Repair and Maintenance
Oil Sampling Programs
Shop Staffing Levels
Late Equipment Delivery Penalties
Equipment Specifications
Fuels
E-Mail Addresses/Internet Connections
Incident Response Vehicles

The group took a field trip to the Post Falls DOT Maintenance Shop to review IDOT maintenance equipment. The 1998 conference will be hosted by Wyoming DOT in Cheyenne, August 18–20, 1998.

Fleet Management Information Systems Selection and Procurement

James M. Putnam
Keane, Inc.

A successful fleet management information system selection process merges a structured approach with the user's professional knowledge. Two series of structured questions define needs: those asked of the organization and those asked of vendors. The North Carolina Department of Transportation (NCDOT) defined the equipment and fleet management needs through the structured methodology brought by Keane, Inc., a consulting firm.

The organization must examine itself. These questions set the general direction, and are not expected to be firm or unchanging:

- What are the goals for the fleet management system?
- What information is needed to make strategic and operational decisions?
- What is currently being done?
- What functions and processes do the work?
- What other units must be kept informed about the work?
- What are the functional, hardware, and network requirements?

A strong discovery process will determine what is available in the market to potentially meet the goals and requirements developed. A request for information (RFI) adds detail. Vendors' demonstrations in response to RFI measurements show how they meet most needs, along with how well they understand the way you manage your fleet. Learn from them, but also teach them. Refine the RFI evaluation process to measure responses to the request for proposal (RFP). Then, construct the RFP. Put the identified requirements into clear, concise language. Next, use the evaluation plan developed in the discovery process to evaluate the responses. Finally, select a vendor. Once the vendor has been selected, NC Purchasing and Contract executes a contract to purchase the goods and services selected.

INTRODUCTION

A successful fleet management information system selection process is the result of merging a structured approach with the knowledge of professionals who will be using the software. The consultant developed its Packaged Software Selection and Implementation (PSS&I) methodology to successfully guide clients through packaged software search initiatives, from initial search to conversion and rollout (*1*). The consultant and North Carolina Department of Transportation (NCDOT) applied the methodology in the Business System Information Project (BSIP).

A methodology should provide clear and flexible structural guides rather than rigid rules. Where appropriate, rearrange, remove, or revise entire activities to adapt to the specific needs of the organization. Add activities where the organization requires additional information. It is this knowledge of how to apply the methodology that the consultant brings to the project. The organization brings professional knowledge and purpose. When the knowledge of the consultant is merged with that of the organization, the resulting software selection has a much higher likelihood of satisfying the needs of the professionals across the organization.

A complete and flexible methodology, PSS&I has three distinct phases: Packaged Software Evaluation and Selection, Packaged Software Design Reconciliation, and Packaged Software Implementation. This document will focus on the first of these phases, Packaged Software Evaluation and Selection (*1*).

FIGURE 1 Packaged Software Selection and Implementation methodology.

PACKAGED SOFTWARE EVALUATION AND SELECTION

A prerequisite to beginning this phase is the decision to select a packaged software solution rather than build a custom application. In the case of North Carolina, the roots of that decision date back to the mid-1990s, when NCDOT and the Office of the State Controller concluded that the statewide accounting system could not meet NCDOT's extensive and unique requirements. NCDOT's unique accounting system identifies funding sources and provides management control to projects that construct and maintain the State's transportation infrastructure. Since the State's accounting system was not project oriented, the agencies jointly agreed that NCDOT would explore the packaged financial software marketplace to see if there was a fit. Equipment and fleet management, considered integral to the projects and financial systems being analyzed, was included in the software selection effort. BSIP resulted from that agreement, and subsequently identified and analyzed needs throughout NCDOT (*2*). This has resulted in an RFP for a financial management information system, which includes a fleet management system. This paper will address the fleet management system (FMS) portion of that effort.

Understanding of the information system requirements is essential in the selection of an appropriate software package. Current and future requirements must be considered to ensure that the recommended solution addresses both the short- and long-term needs of fleet managers at every level of the organization. A software application's functional capabilities must be considered in conjunction with the culture, stability, and stated future

direction of the vendor. When governmental agencies and commercial software vendors will be working together for years, selecting an appropriate software vendor as a business partner is a challenging task.

A packaged software selection is made based on both the functional capabilities of the software and its fit to the target hardware environment. The preferred solution will satisfy requirements in both of these areas.

The objectives of the Packaged Software Evaluation and Selection phase are definition of the business and technical requirements that must be satisfied by the packaged software application, preparation of detailed selection criteria against which to evaluate vendor proposals, preparation of the RFP, and selection of appropriate packaged software based on business, technical, and business partner requirements (*1*).

Extensive interaction between the fleet management professional staff and the consultants is required during this phase, in both interview and workshop settings. There are basically two kinds of questions: those asked of the organization and those asked of vendors who hope to supply the software system. In our case, NCDOT defined the equipment and fleet management needs through the methodology brought by the consultant. In the project with NCDOT, BSIP adapted the consultant's PSS&I methodology to use a five-path approach: Project Management, Software Selection, Information Planning and Technical Architecture, Transition Management, and Process Improvement.

For each path, BSIP formed teams composed approximately equally of NCDOT professionals and the consultants. Each team worked separately to develop its area requirements and to collaboratively maintain a common understanding of activities, requirements, and direction. Four of these paths—Project Management, Information Technology, Transition Management, and Process Improvement—are briefly discussed. Software Selection (the shaded path in Figure 2) is the focus and is discussed in more detail.

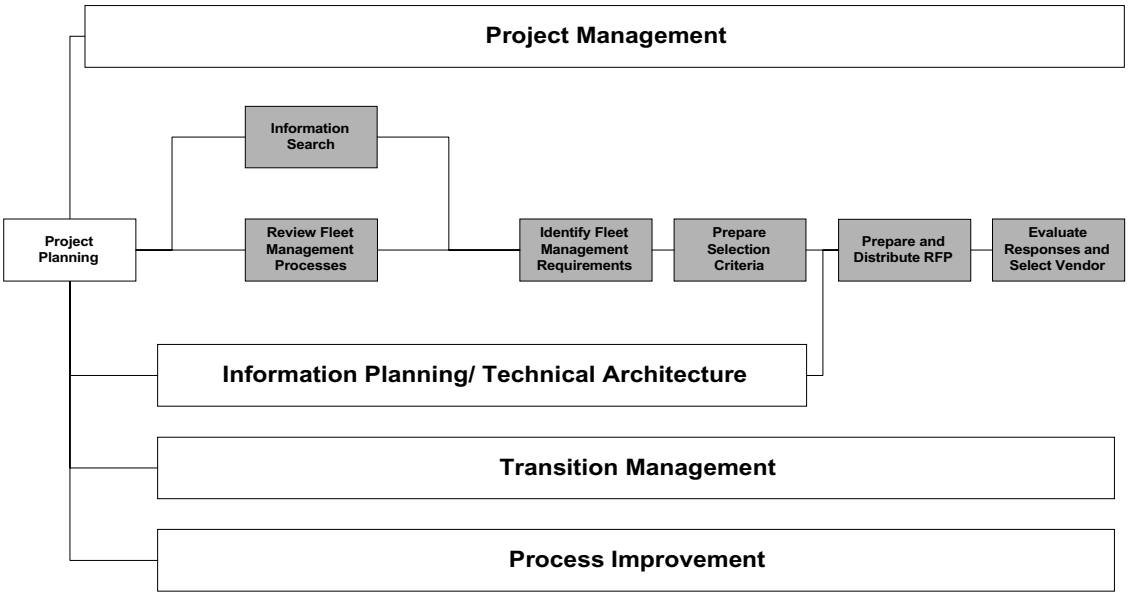

FIGURE 2 NCDOT Software Selection model.

Project Management

A project is a specific activity, with a discrete beginning and end, that produces predetermined results (*3*). The management of each project poses unique problems, yet all projects have common characteristics. Understanding these characteristics and their ramifications can change project management from a "work hard and hope for the best" effort into a rational process. In data processing, the term "project" usually refers to the installation of an entire system. The PSS&I methodology definition allows a different interpretation. Each phase is self-contained and can be a complete project in itself. The first phase, Packaged Software Evaluation and Selection, as adapted for NCDOT, has five paths. Each path consists of one or more activities, has a distinct beginning and end, and produces predetermined results or deliverables.

The consultant's project management methodology, Productivity Management™ (PM), is the first activity in each phase of all the consultant's projects. An ongoing process of accurate task definition, progress reporting, and integration of proven management principles into tasks, PM is a set of project management guidelines that helps ensure the delivery of quality products on time and within budget. Many project management techniques seem to assume that management of a technical undertaking requires a highly technical approach. The consultant's PM has a different perspective. Simple and effective, it applies equally to managing all projects. PM is results-oriented and emphasizes the management and leadership of people. PM is based on six principles (*3*):

1. *Define the job in detail.* Determine exactly what work must be done and what products must be delivered. Explicitly evaluate the environment and address all assumptions.
2. *Involve the right people.* Involve the appropriate users throughout the project, particularly during planning. Involve the appropriate data-processing people. Ensure that each member of the project team participates in defining the goals of the project, including his or her own goals.
3. *Estimate the time and costs.* Develop a detailed estimate of each phase of the development process before undertaking that phase. Estimate components or activities of the job separately. Avoid premature precision. Do not estimate what you do not know.
4. *Break the job down.* Break the job into "tasks" that require no more than 80 hours to complete. Ensure that each task results in a tangible product. The 80-hour rule provides the framework for scheduling and assigning tasks, identifying problems early, confirming time and cost estimates, and evaluating project progress and individual performance.
5. *Set up change procedure.* Recognize that change is an inherent part of systems development. Establish a formal procedure for dealing with these changes and ensure that all parties agree to it in advance.
6. *Agree on acceptance criteria.* Determine in advance what will constitute an acceptable system. Obtain written user acceptance of products throughout the project

so that the acceptance is a gradual and progressive process rather than a one-time event at the end.

Project Planning, the first activity within the Project Management path, is critical to the success of the Packaged Software Evaluation and Selection phase. Phase details, such as a detailed project work plan, will be finalized and communicated to all key project stakeholders and project team members.

As work progresses through the life of the plan, communication with user representatives will be ongoing. This is especially true when potential vendors are contacted and information received must be summarized and presented to project stakeholders. In order to minimize the risk of project delays, it is imperative to establish all necessary lines of communication during this start-up activity.

The project sponsor plays a key role in these preliminary tasks to reinforce the commitment of senior management to the project. This should facilitate the acquiring of personnel and resources throughout the project. All necessary project team orientation will be performed during this activity. To minimize the risk of resource conflicts at a later date, all project stakeholders should be made aware of their required involvement for the duration of the project. An additional consideration, one that is not a part of the software selection process but should be part of management's planning, is supplementary staffing. This staffing, either temporary or permanent, is necessary to perform the daily duties of project team members who have been re-deployed on the selection and implementation efforts.

Information Planning and Technical Architecture

In this path, the technical architecture requirements for the packaged software must be determined and documented. This will involve extensive interaction between the technical Information Systems (IS) staff and the project team. The technical architecture team develops its requirements in collaboration with the other teams. It must ensure that the selected package fits into the NC Statewide Technical Architecture approved by the NC Information Resource Management Commission (NC IRMC). Technical requirements needed for the RFI should easily transfer to the RFP document, and should be timed to be complete as the RFP is prepared for distribution. Architecture limitations that affect the selection of a particular software package should be identified. All processing and transaction volumes should be identified and quantified. Technical architecture considerations include current and future hardware platforms, existing legacy systems and associated interfaces, remote access requirements, number of anticipated system users, database requirements, and performance requirements (*4*).

Transition Management

Any system change of magnitude implies a host of accompanying non-system changes. Large amounts of energy are often expended in the selection of new software and hardware, but very little energy is put toward the impact these changes will have on the organization and its culture. New hardware and software will demand some fleet management processes to change, but more importantly, new hardware and software will

free the organization to streamline and improve processes constrained by the current system. New technology alone will not increase productivity. Organizational and procedural changes must also happen. Managers must integrate the technology, business processes, and organizational structure to achieve the goals they expect from technology (*5*).

Change is difficult for any organization; by definition, change is part of the implementation of any new system. Planning is necessary to meet the challenges of change. BSIP's five-path approach provided the opportunity to separately examine potential opportunities for change. All proposed changes have organizational impacts. Transitional issues are identified by envisioning the proposed changes in the context of the operational environment in which they will be implemented, comparing them to the current operational environment, and determining their impact. Methods must be in place to resolve the identified issues. Training, documentation, and organizational structure support the successful implementation of the software.

Process Improvement

Often, as a result of examining the present system to determine the requirements for a new system, immediate modifications come to light, modifications that can improve the way the organization manages the fleet. Some of these initiatives require minor, easily implemented modifications to the current system. Others may only require procedural or policy changes. Where these initiatives can be implemented prior to a new system's being put into service, a method to get them in place should be established. NCDOT took a proactive stance on process improvement by analyzing and immediately implementing minor software changes, as well as some work process improvements, along with the software evaluation activities.

There are other benefits that come with the implementation of these initiatives. The organization will reap quick benefits while waiting for the long-term benefits that will result from the new system. The field organization is shown that this is not a management-oriented exercise without real, tangible benefits. Actions taken to implement improvements, especially those derived from field interviews, produce a positive attitude from the very beginning and maintain enthusiasm for the project throughout the entire cycle.

Software Selection

The goal of the Software Selection effort is the selection of one or more software solutions to meet fleet management information requirements. This begins with a review of the current market place, conducted partly through standard market research techniques, but primarily through an RFI followed by vendor demonstrations. Following the evaluation of materials received through the RFI process, an RFP is prepared to evaluate and select the appropriate solution. The result of this effort will be the acquisition of a suitable software solution.

Activities in the Software Selection path are the focus of this paper. The activities are listed below, as well as in the shaded boxes shown in Figure 2: Review Fleet Management Processes, Information Search, Identify Fleet Management Requirements,

Prepare Selection Criteria, Prepare and Distribute RFP, and Evaluate Responses and Select Vendor.

The purpose of these activities is to select the optimum package for the organization. Two sets of questions are the means to do so. First are the questions asked of the organization to define its software needs. Second are the questions asked of vendors to determine their ability to meet those needs.

Review Fleet Management Processes, Identify Fleet Management Requirements, and Prepare Selection Criteria are activities that ask questions of the organization. These questions define the current fleet management functions performed, requirements for the future, and selection criteria, including the prioritized importance of the functional requirements.

The Review Fleet Management Processes and Identify Fleet Management Requirements activities provide functional details required to perform the mission of the organization. The Prepare Selection Criteria activity develops a set of measurements used to identify the vendor's ability to meet the requirements developed in other activities. An early set of mandatory and highly desirable criteria is developed to measure the responses to the RFI. These criteria are refined and expanded as the RFP is prepared for distribution.

The Information Search activity asks questions of the vendors. It allows vendors to demonstrate new features and enhanced capabilities. It also defines the vendors' stability, growth, and future direction, as well as their software packages' potential abilities to meet the requirements. These questions and demonstrations increase the organization's knowledge and add to the detailed requirements in the RFP.

The three purposes of the Information Search activity are to expand the organization's knowledge about what capabilities are available on the packaged software market, to provide the organization with a clear base of understanding about vendors' packaged software capabilities in relation to specific requirements, and to add detail to the requirements in the RFP.

Demonstrations of software packages in real-life scenarios developed by the project team allow fleet managers and shop supervisors who will eventually be using the software to see how generic packaged products perform the functions they use daily.

The Prepare and Distribute RFP activity uses all that has been learned in earlier activities to develop clear requirements. Technical requirements gathered by the Information Planning and Technical Architecture team are brought into the Software Selection path for inclusion in the RFP. The Process Improvement path provides input. Lessons learned in the RFI process are incorporated in the RFP, and the RFP is issued.

The final activity in this path is the ultimate purpose of the entire phase. Evaluate Responses and Select Software applies the evaluation criteria to the responses received from vendors. The team may request additional demonstrations and may also travel to locations where similar installations that use the vendor's packages have been installed. At the end of this activity, the selection of the preferred software and vendor is complete. Each of these activities is discussed in the following paragraphs.

Review Fleet Management Processes

Any software selection project, especially in a state government agency, does not exist in isolation. It is important to know the current environment, the relationship to other units within the department, and possibly the relationship between other state agencies or departments. This activity begins by developing a high-level perspective of the current organization and its strategy, goals, and objectives.

The strategy statement, usually derived from existing organizational literature, is important in that it provides a guidepost for understanding the relationship of fleet management to the overall purpose of the department. With the strategy stated, specific goals for fleet and equipment management can be determined.

This review identifies objectives and essential functional capabilities used to drive the selection process for the packaged software. Four to five bullet points list overall objectives for the packaged software and relate to an organizational strategy to be enabled by the software. They should be fairly specific on any functional process objective such as reducing equipment downtime, reducing specific costs, providing information support for certain processes, and so forth.

The fleet's functional processes are mapped so that a high-level understanding of the organization can be developed. Next, the target processes are identified. Critical to success, target processes are required and form the core of the functional requirements. Large-scale software selection requirements are described here. This activity is the major input source in identifying the fleet management requirements.

This task is simpler if the organization has previously undergone a process mapping exercise to document the fleet management processes. If the organization has undergone a re-engineering exercise, then the redesigned processes should be considered as the target processes rather than the current processes.

The review of key process inputs and outputs involves interviews, work review sessions, and focused facilitated sessions to add depth and detail to the organization's target processes. Workshops and facilitated sessions were held across the state. Personnel at every organizational level contributed, including Division superintendents, office managers and data-entry clerks, shop supervisors, mechanics, and inventory and parts people.

This task gathers all the information required to develop detailed data flow or relational diagrams of the current processes. This includes the inputs to a process or sub-process, the outputs of that process, and any system interfaces or reports. Copies of relevant input forms, reports, and screens are used to determine data elements. Emerging requirements for the new system are documented.

Information Search

The purpose of this activity is to develop or expand the fleet management professionals' base understanding of existing software package capabilities as solutions that can possibly satisfy their functional requirements. There are five tasks within this activity: Market Research, Preparation and Distribution of the RFI, RFI Assessment, Demonstrations, and Qualitative Assessment. This activity can occur in parallel with the Review Fleet Management Processes activity (see Figure 2).

Market Research This initial activity begins to identify suitable software packages and

to determine potential software vendors. It involves a high-level investigation of software vendors in order to assemble a list that could satisfy the application's requirements. Possible criteria include technical environment (such as target hardware and/or specific architectural configurations), specific database management system, fleet management software modules required, essential or market-specific functional requirements, and geographic location of the vendor.

The initial search can be made from a number of information sources, including an on-line vendor database, the Internet, industry publications, previous project experience, and fleet managers' and consultants' industry knowledge and contacts. Using knowledge gathered in the initial search and early requirements gathered in the Review Fleet Management Processes activity, the BSIP team prepared an RFI.

Prepare and Distribute RFI The BSIP team expanded its review of the current marketplace by issuing an RFI to equipment and fleet management information systems vendors. The RFI asked the vendors if, and how, their software could meet the requirements. Each vendor was encouraged to participate in this RFI process in order for NCDOT to consider the impact of its product on business practices and vice versa. No vendor was excluded from the RFI process, or from the subsequent RFP process.

The Software Selection, Information Technology, Transition Management, and Process Improvement teams worked together to develop an RFI that would solicit a full set of information from vendors. The RFI was constructed similarly to an RFP, so that later restructuring for the RFP would be minimized. The RFI solicited information about vendor characteristics; software upgrade history; available and recommended training; functional requirements; technology and architecture requirements; cross-functional requirements, such as reporting tools, security, and ease of use; and software, implementation, and ongoing costs (*6*).

RFI Assessment The RFI process provided both NCDOT and vendors the opportunity to learn. NCDOT gained knowledge about software applications available on the marketplace and also became more aware of how software functions could change the way it does business. This, in turn, sharpened the ability of NCDOT to clearly state requirements. Vendors gained an appreciation of the way NCDOT accomplishes its mission, and some vendors learned that it is not a good idea to insist that NCDOT perform a function to match their software.

The biggest challenge of this task is to determine the high-level screening criteria in parallel to determining the technical architecture and business requirements. The target business processes may not be prepared at the time that this task starts; however, a cursory understanding of the processes is sufficient to determine the high-level screening criteria (*1*). The teams work together to develop the criteria. The initial criteria are later expanded and modified to become the evaluation criteria for the RFP.

Systematic assessment of responses to the RFI informed NCDOT about vendor package capabilities and their applicability to NCDOT. The assessment process illustrated for NCDOT staff the discipline of software evaluation in preparation for the RFP cycle.

Information received from vendors during the RFI process was also used to

develop high-level systems implementation and ongoing cost estimates. This provided NCDOT with the base information required to decide how best to proceed. The cost estimates were used to estimate funding for subsequent phases.

NCDOT conducted an initial assessment of responses to the RFI. After receipt of their response to the RFI, the software selection teams contacted vendors for further explanation. A key point is that packaged software vendors may respond positively to any criteria they can even remotely satisfy, although the way in which they satisfy the criteria may involve extensive workarounds (*1*). Telephone calls with NCDOT fleet managers and consultants participating often clarified some key points of RFI responses.

The responses were read by each of the teams and placed into one of three categories: appears to meet all or most of the requirements with only minor, or no, modifications; appears to meet some requirements, but would require extensive modifications; and does not appear to meet the requirements.

Keeping in mind that the RFI was for information gathering, and that no vendor could be excluded from the RFP process, NCDOT decided to focus on four vendors assigned to Category 1. This does not imply that only four were assigned to Category 1, but that NCDOT, with time limitations, decided to focus on four. The four vendors were invited to present demonstrations of their software packages.

Demonstrations Demonstrations were held to review software and technical functions and to generate ideas for potential process improvements. Demonstrations were scheduled with at least a day in between for review and documentation. Demonstration scripts or business case scenarios (BCS) outline the agenda, as well as some specific fleet management scenarios for the vendors to demonstrate. This avoids demonstrations that are "canned" marketing presentations and ensures more thorough demonstrations relevant to specific requirements (*6*). BSIP developed the BCS as a standard platform to allow each vendor to demonstrate its ability to meet NCDOT's fleet management requirements. Software and procedural details, modified by the Process Improvement team's analyses, were included. Within reason, the BCS balanced NCDOT's requirements against what the vendors could provide. The scenarios attempted to supply an appropriate level of detail about NCDOT fleet management functions to the vendors, so that their resulting demonstrations would use information to which NCDOT staff could relate. At the same time, the vendors were expected to develop their demonstrations in a manner that made sense given the flow and functional capabilities of their product, versus proceeding bullet-by-bullet through the scenario.

Qualitative Assessment Several mechanisms captured comments and qualitative assessments of vendors. The project teams provided feedback after they read a vendor's RFI response, throughout a demonstration, and through post-demonstration review meetings. A preliminary impact analysis of these packages identified the top positive and negative effects on fleet management as a result of implementing the product. Demonstration attendees differentiated between impacts of implementing a new FMS regardless of the specific package and impacts unique to a specific package. Any new system selected would impact NCDOT's business processes in a number of ways. A specific package may have separate impacts on the processes.

Attendees were asked to identify each package's strengths and weaknesses. The

review solicited their concerns about the package, as well as about how they thought NCDOT would have to change its business if the package were implemented, and how the package would be an advantage to NCDOT.

The preliminary assessments were not intended to rank, score, or pre-qualify vendors or their products. They did assist BSIP in determining the feasibility of using vendors' packages to meet NCDOT's fleet management functional and technical requirements.

The Information Search activity and its successor, Identify Fleet Management Requirements, are iterative. Responses to the RFI and successive demonstrations provide increased awareness of application capabilities and identify additional fleet management requirements. The repetitive process of recognizing new capabilities and distilling and clarifying current requirements is one of the primary benefits of the RFI process.

Identify Fleet Management Requirements

The purpose of this task is to review all relevant documentation and to identify and document the resulting fleet management requirements for the packaged software. This documentation typically includes the interview notes and process maps developed in the previous activity, as well as impact analyses from the demonstrations. Other documents include strategic planning documents, organization charts, relevant consulting studies, and so forth (*1*).

Fleet management requirements must include functional requirements that maintain information about the equipment and provide equipment operations with management tools; interface and integration requirements that connect the FMS with other NCDOT and state systems; security requirements; administrative requirements; data base management requirements; standard reporting requirements; query capabilities requirements; ad-hoc reporting requirements; and legacy system (data) integration and conversion requirements.

Fully documented functional requirements constitute a major portion of the final RFP. As such, the fleet management information system's functional requirements should be prepared in such a way that they are easily included as the RFP is written.

Prepare Selection Criteria

The purpose of this activity is to identify criteria against which packaged software solutions will be measured and to establish an objective method to evaluate vendor proposals. Its goal is to determine if a vendor's product could satisfy the requests through the product's current capabilities, customization of functional options and table entries within the standard product, customization of the product's software, development of non-packaged custom solutions, and use of enabling technology.

As noted in the paragraphs on process improvement, this activity may also identify opportunities for improvement to the current system. The opportunities identified should be transferred to the parallel Process Improvement path, for analysis and possible inclusion in process improvement efforts. This activity comprises two tasks: Identify Selection Criteria and Establish Scoring System.

Identify Selection Criteria Based on functional and technology requirements, the project teams must prepare appropriate selection criteria to aid in determining the successful vendor. It is essential that the criteria system accommodate both qualitative and quantitative selection criteria and allow automated measurements where possible. BSIP constructed proposal characteristics, mandatory technical requirements, and highly desirable technical requirements. Specific proposal characteristics are evaluated as part of the RFP. Included in the proposal characteristics is information about the vendor. NCDOT recognized that multiple vendors could associate in a partner relationship to meet RFP requirements. In order to maintain a single point of contact, they required that a primary vendor submit the proposal, with information about every member of the proposed relationship. Important considerations concerning vendors include number of years in operation, size of current installation base, financial viability and stability, and local support facilities (*7*).

Mandatory requirements were those that the fleet managers and field personnel considered as absolutely necessary for the new software to have as a part of the system. NC Purchasing and Contract (P&C) rules demand that all mandatory requirements be met. A "No" response to any mandatory requirement automatically removed the vendor from further consideration.

Highly desired features were those that the fleet managers and field personnel felt added value to the core mandatory requirements. No vendor was expected to offer all of the highly desired features. Each vendor whose package offered the desired feature(s), or who was able to modify the package to accommodate the feature(s), was required to identify the cost to provide that capability.

It is important to develop criteria to assess the vendor's functional and technological vision during this task, despite subjectivity of such an evaluation. There is often a tension between software functionality and technology architecture. For instance, vendors who have converted from older platforms may have transported the functions without taking advantage of graphical user interface features available with newer technologies. The selection criteria should measure effective use of technology.

Establish Scoring System A scoring system is not necessarily an objective means of evaluation. The process one goes through to assign points can be subjective and not necessarily based on facts. In devising its scoring system, NCDOT strove to be as objective as possible. The vendor was required to respond to each requirement with one of four values (*7*):

1. System can accomplish requirement using existing capability.
2. System will accomplish requirement with package modification and will be included in future releases of the package without custom modification to the North Carolina package.
3. System will accomplish requirement with modification and will *not* be included in future releases of the package. Each future release will require custom modification to the North Carolina package.
4. System cannot accomplish feature.

Mandatory requirements only receive values of 1 through 3. Highly desirable features can receive a response of any of the four scoring values. For each desirable feature that receives a score of 2 or 3, a corresponding line in the Cost Proposal requires a cost estimate of the effort to implement. This scoring method takes customization issues into consideration. It is an advantage to NCDOT if the vendor includes custom modifications in the core software package for future releases. If the vendor does not follow this practice, then the selection criteria must determine the methodology the vendor has in place to maintain the custom portion of the software as new releases are implemented.

Prepare and Distribute Request for Proposal (RFP)

NCDOT's goal was to construct true, accurate, and complete requirements. The purpose of this activity is to construct the requirements and supporting information for distribution to vendors in order to accomplish that goal. Within governmental agencies, an RFP usually has a structure and boilerplate content specified by the purchasing unit. Most purchasing units require technical proposals to be completely separate from cost proposals. NCDOT worked closely with the NC Department of Administration's P&C organization to construct an RFP that would provide NCDOT with the optimum fleet management information system. This activity has two tasks: Prepare and Validate the RFP, and Issue the RFP.

Prepare and Validate RFP The RFI process gave NCDOT a running start toward the true, accurate, and complete goal. Vendors who responded to the RFI provided feedback to NCDOT. The business case scenarios (BCS), along with vendor demonstrations of those scenarios, provided an additional method of clarifying requirements. Ambiguous requirements either created numerous questions from vendors or inadequate responses. In either case, the result was that the ambiguous requirements were revised prior to inclusion in the RFP. The RFI process enlarged the scope of NCDOT's thought processes. Requiring the vendors to follow the BCS as closely as possible created a familiar arena for the demonstration attendees. When this method was coupled with the vendor's application of the BCS to the demonstrated software systems, new ideas were generated about the way NCDOT's fleet managers and field personnel could do business. This in turn created additional requirements beyond those of the RFI or BCS. The software selection teams began an iterative process of writing the requirements and reviewing them with professionals in their functional areas. Field focus groups, followed by fleet management interviews, determined which were to be mandatory requirements, and which highly desired features. The teams emphasized P&C's rule demanding that a vendor must meet all mandatory requirements. After several reviews, the functional area stakeholders signed a statement agreeing that the requirements were true, accurate, and complete.

The technical RFP was organized into four main sections, with appendices at the end. The objective was to clearly present the information once, eliminating redundant or confusing information. The sections were designed to be read in the order presented. Each section contains the following information (*7*):

1. *Introduction*—describes the purpose and organization of the RFP, provides

the contact list, and defines some terminology.

2. *Request for Proposal Process*—explains the various activities and details of distributing the RFP, submitting proposals in response, evaluating the proposals, and awarding contracts.

3. *Background*—defines scope, outlines key aspects of NCDOT's business environment as it exists today, and presents background information.

4. *Requirements*—divided into Software and Implementation Services. It also provides Functional Narratives, BCS, and supporting documentation.

5. *Appendices*—provides glossaries, additional reference information, and links (where it was not feasible to include the reference and supporting information).

In the cost RFP, it is critical to identify all costs, both one-time and ongoing, associated with each proposal so that a fair comparison may be made. One-time costs will typically include hardware, software (both system and vendor application software), implementation services (training, documentation, and so forth), and estimated cost of packaged software modifications, based on the gaps between the vendor's package and the fleet management requirements.

Ongoing costs will typically include such items as hardware maintenance, software maintenance and support fees, network and telecommunication costs, and any costs associated with the upgrading of skills of technical and other support staff.

Each of the vendor's RFP responses will differ in the number of workdays for modifications and interfaces as well as in the mix of required resources. The purpose of this task is to quantify the costs of these modifications and interfaces, and to identify any additional implementation costs. Costs were required for licensing, modification to meet mandatory requirements, implementation of service, facilities (for example, space, utilities, telephone, and insurance), and so forth. Highly desired features required costs for each group of defined features. In order to maintain fairness in evaluation, vendors are required to provide a cost for each defined group.

Issue RFP NCDOT and P&C issued the RFP by posting it on their Internet Web site and providing a CD-ROM. No paper copy was distributed. A one-page notification was distributed to those vendors on the RFP vendor list maintained by NCDOT and P&C. Text similar to the notification letter was also placed in public newspapers. Vendors could request a CD-ROM copy of the RFP from the designated P&C contact. NCDOT required that proposals be submitted in a combination of paper and electronic media. For both the technical and cost proposals, one signed paper original and two electronic copies were required. The cost proposal response to the RFP consisted of costs for the mandatory requirements and lines for each group of highly desired features.

Evaluate Responses and Select Software

Activity As with most governmental agencies, regulations prescribe a specific sequence of activities to evaluate software proposals. North Carolina's sequence is (*7*)

- Issue RFP

- Submission of Vendor Questions
- Pre-proposal Conference
- Issue of RFP Addendum
- Proposals Due
- Proposal Evaluation
  - Site visits and demonstrations
  - Final technical proposal evaluation
  - Open cost proposals
- Contract Award and Execution

A less tangible but nevertheless important aspect that can be evaluated, but not used to exclude a vendor from the selection process, is the fit of the vendor "culture" to the fleet management environment. This is important because there will be a substantial implementation project with the selected vendor. Since fleet managers and field personnel will be working closely with the vendor over an extensive time period, it is important but not mandatory that they be compatible. At the time this paper is being prepared, the RFP has been issued, but vendor questions have not yet been received.

Evaluation Methodology The method NCDOT will use to evaluate responses to the RFP, developed in cooperation with P&C, allows a degree of flexibility in selecting the optimum package. A team of evaluators representing the various interests of the State will be formed. The team will be responsible for reviewing all technical proposals and evaluating each proposal based on its technical merit. Cost proposals will be opened and evaluated by the NCDOT team, in conjunction with P&C, only after the technical proposal evaluation has been completed and viable proposals identified.

The first evaluation is of proposal characteristics. A proposal will be excluded unless all proposal characteristics are satisfied. Vendors that satisfy the mandatory proposal characteristic criteria will have their technical proposal evaluated.

Technical proposals have two levels of evaluation. Upon receipt and opening of each proposal, responses to the software requirements will be examined and evaluated. Proposals that do not meet all of the mandatory requirements will be eliminated. The mandatory requirements will be evaluated using the schema devised in the Prepare Selection Criteria activity. Vendors must respond with values of 1, 2, or 3. A value of 4, or a "system cannot accomplish" response, is not a permissible response to a mandatory requirement.

Next, each highly desired feature will be evaluated, using the schema devised in the Prepare Selection Criteria activity. Responses to the highly desired category will also be evaluated using the description associated with each feature.

Vendors may be asked to demonstrate their software to NCDOT using the BCS prepared. These demonstrations, in contrast to those performed in the RFI process, are designed to determine the validity of the vendor's responses to the RFP.

Site visits may be optional, depending on time, budget, and range of proposals received. The purpose of a site visit is to further investigate vendor reliability and strategies by visiting an installation of the vendor's system. Vendor site visits can be a valuable way of validating vendor development and support in a similar operation. Visits

should be to an operation similar to that in which the selected package will be implemented. Another state's fleet operation in which the vendor has an installed system would be ideal. Barring that, NCDOT and the vendor will cooperatively identify a site that is as similar in size and operation as possible. Preparation is required to determine who is going, what material is required, and what operations should be the focus at the vendor site. The persons performing the visit must have a clear method of evaluating the focus operations. Each person should complete an objective and subjective evaluation of the visit.

At this point in the final technical proposal evaluation process, NCDOT will have determined that a set of vendors meets all proposal characteristics and all mandatory requirements, that the set of vendors has demonstrated solutions that meet NCDOT requirements, and (through site visits) that the vendors have exhibited their installed operations in a similar environment.

The final technical proposal evaluation reviews the evaluation team's analyses from the demonstrations and site visits. Based on these analyses, NCDOT expects to be able to determine that a vendor's proposed solution to a mandatory requirement or highly desired feature is unacceptable. NCDOT will be able to exclude a vendor that meets all of the mandatory requirements but is unable to meet the highly desired features that NCDOT determines is critical to its business operations. The final technical proposal evaluation concludes with one or more vendors whose proposals are technically acceptable.

Upon NCDOT completion of the technical evaluation, the cost proposals of firms whose technical proposals are technically acceptable will be publicly opened. The total price of fulfilling the requirements plus the total price of the selected highly desired features offered by each firm will be tabulated. Lowest price will then be used to select the product that meets all of the mandatory requirements, plus the set of highly desired features that NCDOT determined as critical to its fleet management operations.

Contract Award and Execution Award of a contract to one vendor does not mean that the other proposals lacked merit, but that, all factors considered, the selected proposal was deemed to provide the best value to the State. At this point the State will enter into negotiations with the selected vendor to resolve issues related to options, hardware, support, terms and conditions, and other items.

CONCLUSION

NCDOT has worked through the Packaged Software Evaluation and Selection phase of the consultant's PSS&I. It has been a long and tedious process, but one that has been and will continue to be rewarding to NCDOT. Among the benefits of going through the process is that the next phase (Packaged Software Design Reconciliation) and its successor (Implementation) will be easier. They will not be easy, but certainly easier, due to the discipline, knowledge, and relationships developed in this phase.

A set of expectations has been established. The methodology is flexible enough to select a software package to fit organizational needs as varied as financial and equipment operations. The needs of fleet managers, shop supervisors, inventory clerks, and

mechanics were included in the RFP.

NCDOT examined its functional requirements, constructed an RFI to determine market capabilities to meet those needs, and required vendors to demonstrate their product in a real-world environment. As a result, the NCDOT knows more about its needs and how it does business. It knows how to tell vendors and consultants exactly how it wants a particular function to work, and it knows not to be satisfied with protestations that the vendor's way will do it just as well. This skill will be increasingly important in the Design Reconciliation and Implementation phases. NCDOT has constructed an RFP explicitly stating its requirements and measurement criteria to determine the optimum package for the State.

BSIP is a fine example of merging methodology and professional knowledge. The RFP is solid evidence that NCDOT professionals expect top value for their State's dollars. The NC IRMC has determined that the RFP is a new statewide model for organization and approach for all of North Carolina's future procurements of packaged software solutions. The software package selected and implemented will enable NCDOT's fleet and equipment managers to more accurately measure the performance of their equipment, and to extract the maximum value for the State's equipment expenditures. Keane, Inc.—and, in particular, the author—have been proud to be a part of the process.

REFERENCES

1. *Packaged Software Selection and Implementation: Keane Framework for Software Development, Release 1.0*. Keane, Inc., Boston, 1996.
2. *General Assembly: Financial System Implementation Plan.* Business System Improvement Project, North Carolina Department of Transportation, Raleigh, 1998.
3. Keane, J. F., M. Keane, and M. Teague. *Productivity Management in the Development of Computer Applications*. Keane, Inc., Boston, 1984.
4. *Information Technology Action Plan*. Business System Improvement Project, North Carolina Department of Transportation, Raleigh, 1998.
5. *DOT Business System Improvement Project Transition Guide*. Business System Improvement Project, North Carolina Department of Transportation, Raleigh, 1998.
6. Request For Information (RFI). Business System Improvement Project, North Carolina Department of Transportation, Raleigh, 1997.
7. Request For Proposal (RFP). Business System Improvement Project, North Carolina Department of Transportation, Raleigh, 1998.

Reengineering Fleet Management

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Although change is a constant in almost all endeavors, no industry has experienced more dramatic change than fleet management. Twenty years ago, maintaining equipment was generally the only responsibility that the maintenance manager had, and he did that within a budget allocated to him by upper management. Today, the role of the fleet manager has not only expanded, but it is constantly shifting:

- From accepting technology to embracing and pursuing technology;
- From command and control to a shared vision and empowerment;
- From completing tasks to taking responsibility for outcomes;
- From operations specialists to marketing and communications experts;
- From total insourcing or outsourcing to a variety of hybrids;
- From hoarding resources to sharing resources;
- From having hundreds of vendors to forming alliances with a few;
- From following the rules to breaking them in the name of customer service;
- From "fleet only" to total maintenance management;
- From a total focus on cost to total customer satisfaction;
- From viewing departments as separate to embracing cross-functional responsibilities and outcomes;
- From low bid to best bid;
- From a focus on downtime to one on reliable availability;
- From measuring only the general, after the fact, to real-time analysis of detail;
- From shop mechanic to computer technician;
- From individualization to standardization;
- From total ownership of all equipment to maximizing of capital and technology;
- From owning and operating all fuel sites to a combination of strategies, including the universal card;
- From outsourcing warranty work to becoming certified to do it "in house"; and
- From a focus on cost only to leading the way for clean air.

And the list continues. Fleet managers are generally exhausted and have difficulty "stepping back" and prioritizing because there are just not enough hours in the day. For several years now, they have been threatened with privatization and have been continually urged to become more competitive. Unfortunately, they either try to hide for as long as possible or attempt to become more competitive by using outdated paradigms that no longer work or result in performance gains that are too little or too late. They work even harder and exhort their people to do the same, hoping that they will last until they can retire.

There is a better way, but it takes courage and commitment to break free of the "way we've always done it" and to start over with a clean sheet and design a new way of providing service to our customers, both external and internal. Call it reengineering, a term popularized by Mike Hammer, or reinventing, the public sector's response to the same challenge, Americans have responded in record numbers and we are now universally recognized as the most productive and competitive country in the world. We have become so efficient and effective that there is no one even close and experts predict that, unless we slip into complacency—always a possibility, as we have been there before—we will continue, indefinitely, to stay at the top.

We got there by unleashing our competitive spirit and accepting the challenge to be the best. To be the best requires a relentless pursuit of constant improvement in our processes and adding value for our customers. The improvement model that has evolved provides us with a "blueprint" for becoming more competitive. This model, as presented in Mike Hammer's latest work *Beyond Reengineering,* is shown in Figure 1.

As the model indicates, the first step is to determine what the customer wants and needs. Traditionally in our industry we have used written customer surveys, either at the point of service or at a periodic interval, generally every year or longer. With the proliferation of surveys for everywhere we go and everything we do, most of us have lost interest in filling them out, and getting accurate, thorough data has become a challenge. The other limitation is that they are one-way communications without chance of additional clarification or feedback. There are two methods of acquiring accurate customer feedback that are becoming more popular: the telephone survey and customer focus groups. The telephone survey can be very effective if the questions are designed well and if the right person makes the call. No one wants to be surveyed by someone who does not know our industry and is just "filling in the blanks." A good interactive phone exchange can be very effective in uncovering unmet needs of customers. Customer focus groups have become increasingly popular in all industries and, when conducted for fleets, have revealed some very interesting facts. So often what we think is important to customers is either low on their list or does not make the list at all. The open-ended style of focus groups and the ability of customers to piggyback on each other's ideas can be very powerful in helping us discover where we need to be placing our resources.

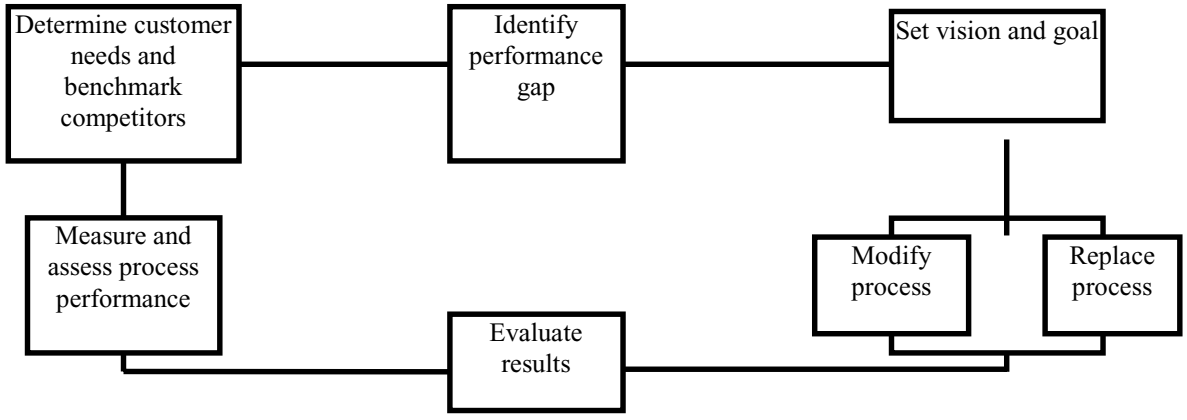

FIGURE 1 Improvement model.

Once we have a clear view of what the customer wants, needs, and expects, we have to find some organizations that are "best in class" in providing these services and then benchmark our numbers with theirs. Probably my greatest frustration with our industry is that we all talk about benchmarking, but when it comes to sharing our real numbers with each other, we start making excuses—e.g., our class divisions are different, or our repair type schemes do not match. At CCG we spent two years standardizing codes and developing 17 benchmarks—and the reports to reflect those benchmarks—so that our customers could compare their operations and learn from each other. We made it as easy as it possibly could be and we are struggling to get participation. We have called, we have sent reminder cards, and so forth, and yet most of our customers have not responded—and many of them have outstanding operations. We have to know and be honest about our numbers and be willing to compare them to the best if we are ever going to achieve world-class competitiveness.

Once we have compared our numbers with the best, we determine what our performance gap is and just how far we have to go. For instance, a mechanic productivity benchmark at an outstanding operation might be 87 percent and ours is 55 percent; that is a huge gap and no amount of "tweaking" is going to close the gap. We will need to throw out our current work order process and begin to develop one that enables, and accounts for, better mechanic productivity. Alternatively, if our productivity is 78 percent, we might choose to use some Total Quality Management (TQM) techniques and self-directed work teams to isolate some opportunities for incremental improvement. It is the size of the gap that determines what type of improvement techniques we will utilize.

No matter what technique we choose to use, however, we must not charge in and begin implementation until we have created a clear vision of the desired outcome, accompanied by some specific goals and implementation strategies. This step is crucial and, without it, no substantive or lasting change will take place. And yet it is where so many fleets stumble and fall. Unless they have hired an outside consultant to facilitate them throughout this step of the process, few will actually spend the time to work with front-line staff to create their own vision, goals, and strategies. They would rather borrow someone else's, and, though this is better than nothing, it is not nearly as effective as spending the time together to really discover our greatest opportunities for improvement. It is a very basic management principle; if they did not create and, thus, do not own the outcomes, they will never really fully invest in them. And when they do not reach the vision and goals, it is never their fault because someone else set them.

Once we have a clear picture of where we are going, it is time to identify the process that must be modified or replaced (depending on the size of the gap) in order to achieve our objectives. A process is a complete end-to-end set of activities that together create value for the customer. It is very important that we not spend too long on examining our processes, because the longer we study them and ask questions about them, the more likely we are to "understand" them and not change or radically redesign them. As John Kenneth Gailbraith once said, "Faced with the alternative of changing one's mind and proving it unnecessary, just about everybody gets busy on the proof." At a minimum, flowcharting our processes is a necessity: pictures so often reveal all the superfluous, non-value-adding things that we have been doing for years, and of which we

are totally unaware. At some point in history, there was a valid reason, a reason that technology has probably now made obsolete.

After the process review, we decide what changes must be made to meet objectives. A key ingredient at this stage in the improvement cycle is evaluation of how well we are pursuing the latest technologies available to assist us in streamlining any step of the process. The single biggest difference in America's meteoric rise in productivity in the last few years is how quickly we embrace and implement new technologies. A very simple analogy (one which assists us in making the technology leap) is that anything that is a left-brain (transaction) activity should be replaced with technological solutions, thus freeing the creative right brain to find new ways to add value in serving customers. The faster we can solve customer problems, the more successful we will be.

Once we have eliminated the unnecessary steps in our processes and added value in as many ways as possible, we then track and evaluate results. There will be no substantive change without accountability, and the evaluation process must be ongoing and consistent, with the results visible to all those who are a part of the process being reengineered. Once we have measured and assessed our process performance for the established objectives in this particular area chosen for improvement, we start the process all over again. There is always room for more improvement; we do not have to be sick to get better.

Though the diagram and the summary make the improvement process sound easy to achieve, it is not. There are several key principles or truths that, if we understand them, can assist us in making substantive change within our organizations—and constant change is a must if we are to survive and thrive in today's increasingly competitive environment.

The first is the need for a change agent, an individual or thing (usually having to do with technology) that forces us to look at things differently. The change agent could be a new hire, someone eager and young, who has not had time to form a lot of bad habits or to "understand" the way we do things around here. It could also be a consultant, who, if skilled enough in implementing the improvement process, can provide courage, direction, and persistence in not quitting before accomplishing all the goals. It helps if this person knows fleet and understands the true complexity of the challenges we face. The change agent could be an audit, a new information system, or the incorporation of a new feature—such as bar coding—to the ones we already have. The change agent could be fear—and it often is—fear of losing our jobs to the privateer who promises better service at a lower price. Whatever it is, it is almost always necessary to have one or more to precipitate substantive change.

Another key feature of reengineering is the importance of a strong leader, one who has courage and the vision to stay focused throughout the process. This leader understands that there will be resistance to change—indeed, if there is no real resistance, then we are not trying to change much—and he or she will stay the course, no matter what. There will be tough decisions to make and, at times, morale will suffer, but the leader knows that he may have to sacrifice the few to save the many.

In today's competitive environment, we understand that we can no longer complete our work sequentially (i.e., first we do one thing, then the next, and so on). We do it simultaneously, a whole lot of things at once, using the pit stop for a racecar as a model of where we need to be. We also understand that our reasoning skills must focus on the inductive model, not the deductive one that served us so well for so long. It used

to be that it was enough to be good at defining the problem and then seeking and evaluating different solutions to it. Now we need to have the ability to see a powerful solution and to then seek the problems it might solve. As Wayne Gretzky said at age 28 when he was asked why he was great, "Because I go where the puck is going to be, not where it is."

Finally, reengineering is scary because it is fast and reckless and filled with mistakes and course corrections. It is not for the meek of heart. But, if we understand the process and the possibilities, we will embrace reengineering and, as a result, have vital and thriving organizations in which to work, organizations that make a difference. Deep down, we all want to make a difference.

REFERENCES

1. Hammer, M., and S. A. Stanton. *The Reengineering Revolution: A Handbook.* HarperBusiness, New York, 1995.
2. Osborne, D. E., and T. Gaebler. *Reinventing Government: How the Entrepreneurial Spirit Is Transforming the Public Sector*. Addison-Wesley Publishing Company, Reading, Massachusetts, 1992.
3. Hammer, M. *Beyond Reengineering: How the Process-Centered Organization Is Changing Our Work and Our Lives*. HarperBusiness, New York, 1996.
4. Senge, P. M. *The Fifth Discipline: The Art and Practice of the Learning Organization*. Doubleday/Currency, New York, 1990.
5. Naisbitt, J., and P. Aburdene. *Re-inventing the Corporation: Transforming Your Job and Your Company for the New Information Society*. Warner Books, New York, 1985.
6. Bennis, W. G., and B. Nanus. *Leaders: The Strategies for Taking Charge*. Harper and Row, New York, 1985.
7. Hammer, M., and J. Champy. *Reengineering the Corporation: A Manifesto for Business Revolution*. HarperBusiness, New York, 1994.

Meeting the Outsource Challenge: Competing for Equipment Maintenance Services

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Outsourcing and privatization are national business trends that are becoming increasingly relevant to public-sector equipment managers. The premise that many of the publicly provided services are better performed by the private sector has been embraced by many members of state legislatures, county commissions, and city councils. The City of Charlotte has adopted a comprehensive managed competition program as a strategy to test this premise and to drive improvements in cost and services to the public.

The City's Equipment Management Division (EMD) recently won a competition with private-sector firms for the right to continue providing vehicle maintenance services to the City of Charlotte. EMD incorporated a number of private-sector business strategies and practices in its winning bid, including performance-based pay, self-directed work teams, and profit sharing. A number of lessons were learned from the competition process, including the importance of organizing for competition, designing business like cost structures, knowing your competition, and being proactive.

Public-sector employees are not accustomed to competing for their jobs. Our competitors are skilled at competition and are continuously seeking opportunities to expand business. In order to survive in this environment, we must "think private" and also seek to maximize the inherent advantages we have as nonprofit governmental agencies.

WHY ARE OUTSOURCING AND PRIVATIZATION ISSUES?

Privatization of public-provided services continues to be a hotly debated issue. Many members of state legislatures, county commissions, and city councils have embraced the premise that the private sector can deliver most public services better, faster, and more cheaply than can public employees. Moreover, many businesses and public agencies have concluded that most support services are not "core" and, therefore, are candidates for outsourcing.

A recent study in the journal *Public Works* (*1*) reported that 32 percent of public-sector managers feel that the trend toward privatization of equipment maintenance services will increase in the future. Only 2 percent believe that the trend will decrease. There were similar results for other public works functions, so the consensus is that our customers will also face the privatization issue with increasing frequency.

Outsourcing is another trend that bears watching. Groups that provide services to internal customers, such as information technology or equipment management organizations, are especially vulnerable to this trend. This is the case not only because these services are seen by many as not being core services, but also because many internal services providers have fallen well short of meeting their customers'

expectations. Richard Hays observes that internal services providers share the following characteristics (*2*):

- They are large, collectively representing more than 40 percent of employment in most firms.
- They are important. They are key early contributors to a chain of service that ends with the final customer.
- They are linked in issues and concerns, sharing common critical success factors and constraints.
- They are sources of frustration. Many are the targets of criticism for service that is seen as ineffective and expensive.

Large and expensive, important but ineffective—these linkages are what drive some customers to seek alternatives to internal service organizations.

Clearly, privatization and outsourcing are national trends that are becoming increasingly relevant to public equipment managers—due to the frequency of their application and because both trends lead decision makers to the conclusion that our organizations would be better off hiring someone else to do our jobs.

Within this environment it is essential that public equipment management organizations prove their worth to their customers and to their agencies. This proof can be provided in a number of ways, including benchmarking, customer satisfaction surveys, and consultant studies. However, there is no better way to prove that you are best in class than by beating formidable opponents in open competition on a level playing field.

Done properly, competing and winning provides irrefutable evidence that the in-house service provider is the provider of choice for its customers. Successfully risking it all in competition provides a powerful argument to counter the privatization political agenda and the latest management theory du jour (e.g., “steer, don’t row”). Can the same be said for a benchmarking study?

CHARLOTTE’S MANAGED COMPETITION PROGRAM

The City of Charlotte has adopted a comprehensive managed competition program as a method of ensuring that taxpayers receive the best services at the lowest cost. Whether the service provider is public or private is not an issue for most service areas (public safety and regulatory services are an exception). The bottom line is who can demonstrate that they can perform a service better, faster, and more cheaply. As a result, nearly every service provided by the City that is also available from private-sector firms is a candidate for competition.

The competition process in Charlotte is elaborate and time consuming. It has to be, in order for the program to have credibility with City Council and private-sector firms. Great effort is expended to ensure that the playing field is level—that City services are fully costed and that there are no unfair advantages for the in-house competitor. Inherent advantages such as nonprofit status are fine. However, advantages such as having exclusive access to historical cost records or not having to pay rent on facilities or depreciation expenses are not allowed.

A great deal of effort is also expended to ensure impartiality and unbiased evaluation of proposals. Therefore, City Council has appointed a citizen-based Privatization and Competition Advisory Committee (PCAC). All major competitions are guided by an independent evaluation team comprised of members of the PCAC as well as City staff who are not involved with the service group that is competing. The largest competitions are also likely to have technical consultants assisting the evaluation team in writing the Request for Proposals (RFP) and in evaluating proposals.

The competition process in Charlotte begins with each Key Business Unit preparing a competition plan. This plan identifies services that are most appropriate for competition and the anticipated timing of upcoming competitions. A Request For Qualifications is issued on the larger and more complex projects in order to pre-qualify bidders. This strategy avoids the potentially difficult situation of having to explain to City Council that the small company that submitted a very attractive low bid is not qualified to do the work. After pre-qualifying vendors, an RFP is developed by the organization that manages the service to be bid. The evaluation team and the PCAC review the draft RFP. The pre-qualified bidders are also invited to review and comment on the RFP. Finally, a mandatory pre-proposal conference is held.

The organization that will be competing for the service must establish a bid team that will be separated from any proposal evaluation duties. The bid team is treated the same way as the other proposers. As previously noted, the in-house proposal must be fully costed and include all applicable overhead costs. In order to accomplish this, the City has established a comprehensive cost allocation plan that distributes all citywide overheads to each department. The avoidable amount of these costs as well as other layers of overheads are then included in the in-house bid.

After proposals have been submitted, the evaluation team reviews the proposals and recommends awards based on previously established evaluation criteria. The PCAC reviews the recommendation and forwards the issue to City Council for final approval.

This is just an overview of the major steps involved in a service competition in Charlotte. The process is designed to be fair and to produce credible results that can be supported by the community. To date, 38 competitions have been held, with City organizations winning 28 and the private sector ten. A total of $4.4 million in savings has been identified from competition and privatization, and 108 positions have been eliminated.

EMD VEHICLE MAINTENANCE COMPETITION

With a total of 3,600 units, the City's fleet is one of the largest in the Southeast. The replacement value of the fleet is approximately $100 million. With the exception of Transit Buses and Aviation Department vehicles, the entire fleet was covered by the competition.

The competition process for vehicle maintenance services began in winter of 1996 with issuance of the Request for Qualifications. Three firms were found to meet the qualifications (the City, Ryder, and Tecom), and two were found not to meet required qualifications (experience with large, diverse fleets and financial strength). The RFP was drafted in early 1997 and, after much review, was issued in July. Proposals were due in September. The evaluation process was completed in October, and contract services began on January 5, 1998.

As with any complicated legal document, the RFP was a lengthy and detailed document. Some of its more-important provisions are noted below:

- The contract term is for 3 years with two 1-year renewals at the City's option.
- Fleet asset management services such as replacement planning, specifications, and other administrative activities were not included in the competition and remain with the City.
- The contractor does not have a guaranteed monopoly but will have to continue to exceed customers' expectations in order to retain their business.
- The contractor must use the City's Fleet Management Information System.
- The City's employees were at risk since the contractor was under no obligation to hire existing staff.
- Use of the City's four shop facilities was provided to all bidders for $1 per year.
- Services were separated into two types: *target services*, which are routine and predicable activities for which proposers had to provide a fixed annual bid, and *non-target services*, unpredictable activities over which the contractor has no control. These services include accident damage repair, equipment modifications, and damage caused by acts of nature. Proposers had to provide time and materials rates for these services.
- Detailed standards of maintenance were established to provide bidders with baseline expectations for the continued condition of the City's fleet.
- Financial incentives were established for exceeding performance standards in the areas of fleet availability, repair service turnaround time, and preventive maintenance program compliance. Liquidated damages were also established for failure to meet standards.
- Any savings from the target services bid will be shared with the contractor on a 50/50 basis (gainsharing).

Preparing the City's Bid

EMD formed a bid team to prepare the City's proposal. This team consisted of the division director, the vehicle maintenance manager, a mechanic, the division's business manager, and a member of the City's human resources staff. EMD also hired a consultant (Spectrum Consultants) to identify uncompetitive practices and to assist the bid team in proposal preparation. The bid team focused on adopting a number of private-sector business practices that would improve EMD's competitive position. Some of the key bid provisions are listed below:

- *Fewer/higher paid staff*. Over the past 8 years the size of the maintenance staff has been reduced from a high of 90 in 1993 to 67 positions that were included in the bid. During the same period the size of the fleet increased by 12 percent.
- *Fewer supervisory and support staff*. Two parts and two service writer positions were eliminated. In addition, first line supervisors are expected to work on the shop floor 50 percent of the time.

- *ASE (Automotive Service Excellence) certifications required*. Achievement of ASE Master is required for highest-level technician position. A minimum of three certifications is required for journey level.
- *Self-directed work teams*. High-involvement team training has facilitated the reduction in supervisory and support staff as technicians have taken responsibility for making more business decisions.
- *Increased overtime and training budgets*.
- *Incentive pay and performance bonuses*. EMD included $50,000 in the bid, to pay bonuses for such items as exceeding flat rate job standards, employee of the quarter and year, earning Automotive Service Excellence certifications, and safety awards. In addition, bonuses are also available for exceeding contract performance standards. These bonuses are paid on a team basis.

A summary of EMD's first-year bid is included in Table 1.

TABLE 1 Equipment Maintenance Division First-Year Bid

COST FACTOR	FIRST-YEAR BID ($ million)	PERCENTAGE OF TOTAL
Salaries and benefits	2.7	41.5
Parts	2.2	33.8
Sublet services	1.0	15.4
Operating expenses	0.4	6.2
Overhead	0.2	3.1
Total	6.5	100.0

Evaluating the Bids

To provide technical expertise in evaluating proposals, the evaluation team retained the consulting firm of David M. Griffith. Proposals were evaluated in terms of the 3-year net present value of the fixed bid for target services, transition costs, and an estimate of non-target services costs based on the rate structure contained in the bids and the City's historical experience. A summary of the bids for a three-year term is detailed Table 2.

TABLE 2 Summary of Bids for Three-Year Term

SERVICES	EMD ($ million)	RYDER ($ million)	TECOM ($ million)
Target	20.6	23.4	24.2
Non-target estimate	3.5	2.8	3.2
Total	24.1	26.2	27.4
Difference (%)	0%	+ 9%	+ 12%

LESSONS LEARNED

Participating in a managed competition is a very informative process. Every aspect of the operation must be examined in detail for relevance, efficiency, effectiveness, and cost. You must sharpen your understanding of your customers' business requirements and also take steps to understand your competitors' strengths and weaknesses. Finally, you must develop new sets of skills in areas such as marketing, advanced customer service techniques, business planning, profit and loss analysis, team building, finance and accounting, contract monitoring, and incentive pay plans. Public-sector managers and employees have not traditionally required proficiency with these skill sets. Yet proficiency with these skill sets is a prerequisite to success in a competitive environment. EMD learned a number of specific lessons in the process of winning the competition. Most lessons learned are related to the themes detailed above and include the following:

- *We are not the shop, the garage, or maintenance.* Many view our organizations as a bunch of grease monkeys out in our dingy shops changing oil and fixing flat tires. We must change this view and effectively market our services so that leadership of our agencies understands the importance, impact, and value of our operations. We must foster an image that we are asset managers in charge of delivering essential mobility services to our customers.

In Charlotte, our services impact the cost of nearly every service provided by the City, impact the productivity of nearly every City employee, support emergency services making the difference between life and death, and support maintenance of the City's infrastructure—all of which make possible a thriving economy and high quality of life. Our success is vital to the success of our customers. I know this, and you know this, but does the head of your agency know this? Being in a position to answer emphatically "yes" is important to success in competition and is a key to long-term survival for any internal service provider.

- *Know your costs; design business like cost centers.* A thorough and intimate understanding of all of your cost factors is essential. You cannot manage cost if you cannot accurately measure cost. We found that many agencies that we contacted for benchmarking information either did not know their costs (all they had was high-level budget information) or did not understand their costs (when we asked for fully burdened labor rates, we often received answers such as "$15 to $20 per hour").

One way to better understand your costs is to construct separate cost centers around your various lines of business. Therefore, separate cost centers (and budgets) should be established for asset management activities, maintenance, parts, sublet services, fuel, and motor pool activities. A separate charge back methodology should also be established for each cost center (e.g., a monthly rate for asset management, a percentage markup for parts, and direct billing for maintenance services rendered). Not only does this provide improved clarity and allow more intelligent management decisions, but it also improves your competitive position by correctly assigning costs away from services

that will be subject to competition (such as maintenance), instead assigning them to services that will be excluded from competition (such as asset management).

- *Competition can come from many sources.* Privatization companies (such as Ryder Managed Logistics Services, Tecom, Baker Support Services, and Butler Fleet Services) are not the only potential competition for public-sector equipment managers. National leasing companies such as GE Capital are interested in expanding from their traditional customer base of commercial fleets. As greater numbers of public agencies consider leasing as an option to finance their equipment acquisitions, leasing companies view the public sector as potential customers for the full range of comprehensive fleet services that they currently provide to many businesses.

Another potential competitor for the public-sector fleet business is the electric utility industry. Facing fierce competition due to deregulation, power companies are downsizing operations, including fleets. As a result, their fleet organizations have excess capacity in personnel and shop facilities, and are seeking additional customers. Even small, local vehicle repair businesses can be powerful competitors for the public-sector fleet business. The current primary contractor for Los Angeles County grew from a small local repair company to a subcontractor of the original prime contractor (Holmes and Narver) to assuming the role of prime contractor and winning a subsequent renewal contract.

A final source of competition deserves special attention. Our customers can be the most likely reason that competition becomes an active issue for public-sector equipment managers. This is so because our customers themselves are under increasing pressure to hold competitions for services. More and more public agencies are holding competitions for a wide range of public works services, including refuse collection, street sweeping, water and sewer plant operation, paratransit services, and road maintenance. We all realize that equipment represents a major cost factor for many of our customers. Therefore, when they are under the gun of competition, so are we. Do not be surprised if, one day soon, a major customer knocks on your door requesting a 3-year bid for equipment maintenance services to be incorporated in his competitive proposal. By the way, what would the impact be on your operation if one of your larger customers lost a competition and went out of business?

- *Know your competition.* You should always be in tune with your competitive position in the equipment maintenance marketplace. How do you compare with other public-sector fleets in your area? How do you stack up against the best in class in your region? Most importantly, how do you compare to potential competitors such as the local electric utility, privatization companies such as Ryder, or local equipment repair companies? You should visit your competitors. Understand what they do differently from what you do, and understand their weaknesses as well. Then, incorporate those business practices that make you more competitive.
- *Organize for competition.* Developing a lean and mean organization chart is an important step towards being competitive. Public-sector fleet organizations are often overstaffed, with high supervisor-to-technician ratios and excess administrative positions. This is a serious problem for these fleets, not only because it hurts their competitive position, but also because it is generally difficult to quickly reduce staff or change position classifications in the public sector. In Charlotte we were fortunate in that we had

a number of years of lead-time to prepare for competition, to reduce staff through attrition, and to make incremental changes. Additional changes were included in our bid, but the changes would have had to be drastic if we had not started the re-engineering process years earlier.

- *Be customer centered.* Do not forget your customers during the debate over competition. Being competitive means more than having low cost, productive shop operations. The real goal is to make your customers' operations more productive. This cannot be accomplished only by providing the best services at the lowest cost; it also requires a focus on understanding and meeting cutomers' needs. This means providing extended service hours, offering field services, using vendors that are convenient to remote customers' locations, and so forth. In Charlotte, it also means fostering a close partnership with our customers and involving them in all significant business decisions through having our largest customers sit on a Board of Directors for our business.
- *Be proactive.* Privatization and competition are real trends within our industry. Therefore, it must be a priority for all equipment managers to get out in front of the trend and become experts in this field. I have received a number of panic-stricken calls from equipment managers who just left the City Manager's office with instructions to get their numbers together by the end of the week for comparison to numbers provided by a privatization company at a meeting with the Mayor the day before. This kind of situation happens. If it happens to you and you are not already prepared, you may have a serious problem.
- *Involve your employees.* Competition, privatization, re-engineering, and right sizing all mean one thing to employees—their jobs are at risk. If your organization is getting involved in one of these programs, employees' stress levels will go up, the number of wild rumors will increase, and morale will suffer. In order to minimize this process, it is important to keep employees involved early. There may be someone in your organization who can help you develop a communications plan. We took advantage of advice from the City's Corporate Communications group. Our efforts to build a team-based organization also helped foster better communications.

CONCLUSIONS

I have spoken with many equipment managers who view privatization and leasing companies as the enemy. These companies are cast in the role of villains who will not hesitate to lie, cheat, and steal in order to wrest our customers away from us. I do not agree with this view at all. The privatization and leasing companies are good at what they do and most often add value to their clients' operations. Theirs is a competitive industry and they are continuously seeking good business opportunities. If you represent a good business opportunity for them, then you only have yourself to blame.

Successfully winning the managed competition in Charlotte was very gratifying and is certainly the highlight of my professional career—not only because winning feels better than losing, but also because we are very proud of the positive changes that we were able to incorporate into our bid. Only through risking it all in competition were we able to gain performance-based pay, incentive bonuses, and profit sharing. Competition affords an opportunity for public agencies to accomplish things that would never be

possible in the normal course of business in our bureaucratic, civil service–based environment.

Ours is a competitive society. Competition is all around us. The reality of the new world order is that more and more public agencies will be forced to compete. Competition is neither good nor bad; it is simply the way our business will be conducted in the future. Public-sector employees are not accustomed to competing for their jobs. However, our competitors are skilled at competition. Thus, in order to keep our jobs we must become competitive and we must be prepared. That is the way it is. Predator or prey, eat or be eaten. Faced with this reality, you really have no choice. If you are going to play this game, play to win.

REFERENCES

1. Privatization Continues as a Hot Topic. *Public Works*, Vol.128, No. 10, September 1997.
2. Hays, R. D. *Internal Service Excellence: A Manager's Guide to Building World-Class Internal Service Unit Performance*. Summit Executive Press, Sarasota, 1996.

Status Report: EPAct and Clean Fuel Fleet Programs

Richard Kolodziej
Natural Gas Vehicle Coalition

PRESENTATION OUTLINE

Federal Fleet Mandates

- Clean Air Act of 1990
  - Air pollution driven
- Energy Policy Act of 1992
  - Foreign oil dependence driven

Clean Air Act of 1990

- Phase-in of lower tailpipe standards
- Controls on cold-start and evaporative emissions
- Cleaner fuels
- Inspection and maintenance programs
- Clean Fuel Fleet Program

Clean Fuel Fleet Program Coverage

- Originally 22 nonattainment areas
- Six areas remain: Atlanta; Washington, D.C., metropolitan area; Chicago–Gary–Lake County; Milwaukee-Racine; Denver; and Baton Rouge
- Fleets with 10 or more centrally fueled vehicles
- Vehicles up to 26,000 lbs

CFF Fleet Obligations

- Start date: MY 1999
- Percentage of new vehicles must be LEVs (certified by U.S. EPA):

	1999	2000	2001
LDVs	30%	50 %	70%
HDVs	50%	50%	50%

- All fleets covered: government and private

Clean Fuels

- Focus on vehicle emissions
- All fuels may compete (including diesel and reformulated gasoline)
- Vehicles may only be operated on fuels used to certify them to LEV standard

Energy Policy Act of 1992 Fleet Program Coverage

- Federal (FY 1993)
- State (MY 1997)
- Fuel providers (MY 1997)
- Private and municipal fleets (MY 2002?)
- Centrally fueled fleets of at least 20/50 light-duty vehicles
- Located in more than 125 MSAs with populations of 250,000
- Access to alternative fuels and alternative fuel vehicles

EPAct's Alternative Fuels

- Methanol (including M-85)
- Ethanol (including E-85)
- Propane
- Alcohols
- Hydrogen
- Natural gas (CNG and LNG)
- Biological fuels (B-100)Coal-derived fuels
- Electricity

Federal Fleet AFV Purchase Obligations

- 1993: 5,000
- 1994: 7,500
- 1995: 10,000
- 1996: 25%
- 1997: 33%
- 1998: 50%
- 1999 and after: 75%

State Fleet AFV Purchase Obligations

- MY 1997: 10%
- MY 1998: 15%
- MY 1999: 25%
- MY 2000: 50%
- MY 2001: 75%

Fuel Provider Fleet AFV Purchase Obligations

- MY 1997: 30%
- MY 1998: 50%
- MY 1999: 70%
- MY 2000 and after: 90%
- Must use alternative fuels

Private and Municipal Fleet AFV Purchase Obligations

- ANOPR issued on April 17, 1998
- Could expand mandates to private fleets, municipal fleets, and possibly urban buses
- Comment period closed July 15, 1998
- Final rule must be completed by January 1, 2000
- Program start date: MY 2002.

Natural Gas Vehicles: Availability, Cost, and Benefits

Richard Kolodziej
National Gas Vehicle Coalition

PRESENTATION OUTLINE

Public Policy Benefits of NGVs

- Clean, Healthy Air
  - NO_x
  - CO
  - Toxics
  - VOCs
  - Particulate
- Climate Change
- Energy Dependence
  - Balance of trade
  - Jobs
  - Defense risks
  - Economic risks

Light Duty OEM NGVs—Model Year 1998

- Ford (800-ALT-FUEL)
  - Crown Victoria sedan (dedicated)
  - Contour/Mondeo sedan (bi-fuel)
  - Econoline vans (dedicated and bi-fuel)
  - F-series pickups (dedicated and bi-fuel)
  - Expedition SUV (dedicated)
- GM (888-GMAFT4U)
  - GMC/Chevy 2500 pickup (bi-fuel)
  - Chevy Cavalier sedan (bi-fuel)
- Honda (888-CCHONDA)
  - Civic Sedan (dedicated)

Light Duty OEM NGVs—Model Year 1999

- Chrysler
  - Mid-size van (dedicated)
  - Maxi-van (dedicated)
- Toyota
  - Camry sedan (dedicated)
- Volvo
  - S80 sedan (bi-fuel)

1999 EPA LEV Certified NGVs

- Chrysler: Dodge Ram Van/Wagon (dedicated): ULEV/ILEV*
- Ford: Crown Victoria sedan (dedicated): ULEV/ILEV
  Econoline vans (dedicated): ULEV/ILEV
  F-series pickups (dedicated): ULEV/ILEV
  Contour sedan (bi-fuel): LEV on CNG
  Econoline vans (bi-fuel): LEV on CNG
  F-series pickups (bi-fuel): LEV on CNG
- GM: GMC/Chevy pickup (bi-fuel): LEV on CNG*
  Chevy Cavalier sedan (bi-fuel): LEV on CNG*
- Honda: Civic GX (dedicated): ULEV/ILEV

* Certification in process

The World Wants NGVs

- Europe
  - Italy
  - England
  - Germany
- Asia/Pacific
  - Australia
  - Indonesia
  - Malaysia
  - Japan
  - Korea
- North America
  - Canada
  - Mexico
- South America
  - Venezuela
  - Argentina
  - Brazil
- Other
  - Egypt (Cairo)
  - Iran
  - Uzbekistan

Available Natural Gas Engines

- Caterpillar: 3126; C-10; C-12
- Cummins: B5.9; C8.3; L10G
- Deere Power Systems: 6.8L; 8.1L
- Detroit Diesel: 50G
- Mack: E7G
- TecoDrive/Crusader: 4.3L; 7.0L

1999 EPA LEV Natural Gas Engines

- Baytech:
  - Certified conversions for three engine families
  - Rated HP range: 177–122
  - LEV and ULEV
- Cummins:
  - Nine certified engine families
  - Rated HP range: 195–300
  - LEV and ULEV

More Truck Manufacturers Offer Natural Gas Models

- Freightliner
- Kenworth
- Peterbilt
- Mack
- Volvo GM
- Crane Carrier
- Athey
- Elgin
- Ottawa
- SISU

More Bus Manufacturers Offer Natural Gas Models

- Transit Buses
  - Orion
  - NeoPlan
  - El Dorado
  - North American Bus
  - New Flyer
  - NOVA
- School Buses
  - Blue Bird
  - Thomas Built
- Shuttles
  - El Dorado
  - Blue Bird
  - Champion
  - Goshen
  - Metrotrans
  - North American
  - Transit
  - Orion

Factors Making NGVs Less Expensive to Own and Operate

- Federal Incentives
- State Incentives
- RD&D
- Competition
- Economies of Scale

Appendix A

12th Equipment Management Workshop: Final Program

Austin, Texas

Sunday, August 2, 1998

11:00 a.m. – 12:30 p.m.	REGISTRATION & INFORMATION
12:30 - 3:30 p.m.	**TOUR** • TxDOT Austin District Headquarters, Warehouse and Shops Demonstration of an automated crack sealer developed at the University of Texas
4:00 - 6:00 p.m.	REGISTRATION & INFORMATION

Monday, August 3, 1998

7:00 a.m. - 5:00 p.m.	REGISTRATION & INFORMATION
7:00 - 8:30 a.m.	CONTINENTAL BREAKFAST
8:30 - 9:10 a.m.	**OPENING SESSION** John M. Burns, Jr., *North Carolina Department of Transportation,* and *Chair of TRB Committee on Equipment Maintenance,* presiding
Welcoming Remarks:	• Charles W. Heald, P.E., Executive Director, *Texas Department of Transportation* • Curtis D. Reagan, P. E., Texas Division Administrator, *Federal Highway Administration* • Lawrence J. Zatopek, General Services Director, *Texas Department of Transportation* • Glenn R. Hagler, Equipment Purchasing Manager, *Texas Department of Transportation*
9:10 a.m. - 3:00 p.m.	**IMPROVING EQUIPMENT THROUGH RESEARCH** Doug Nielsen, *Arkansas State Highway and Transportation Department*, presiding
9:10 a.m.	**From Concept to Reality: Advanced Technology and the Highway Maintenance Vehicle** Duane E. Smith, *Iowa StateUniversity*
9:45 - 10:15 a.m.	BREAK
10:15 a.m.	**AASHTO's Winter Maintenance Program: A Proactive Approach to International Technology Transfer** Leland D. Smithson, *Iowa Department of Transportation*
10:50 a.m.	**Texas DOT Vehicle Fleet Warning Light Policy Research** Gerald L. Ullman, *Texas Transportation Institute*
11:25 a.m.	**Development of Guidelines for Control of Radio-Frequency Interference** Thomas F. Trost, *Texas Technological University*
Noon - 1:00 p.m.	LUNCH
1:00 p.m.	**Management and Selection System for Highway Maintenance Equipment** David H. Fluharty, *Technology Transfer Center, University of New Hampshire*

1:45 p.m.	**Research in Support of State Equipment Fleets: Closer Than You Think** Steven J. Lorenc and Leonard E. Bernold, *Construction Automation and Robotics Laboratory, North Carolina State University*
2:30 p.m.	**Review of Current Fleet Management Research and Solicitation of Problem Statements** Doug Nielsen
3:00 - 3:30 p.m.	BREAK
3:30 - 5:00 p.m.	**HUMAN RESOURCE MANAGEMENT** H. Lee Hax, *South Carolina Department of Transportation*, presiding
3:30 p.m.	**Skill-Based Pay Program for Mechanics** Dan Domico, *North Carolina Department of Transportation*
4:15 p.m.	**New Art of Hiring Smart: Matching the Right Person to the Right Job** Arlen T. Swenson, *International Institute of Marketing Excellence*

Tuesday, August 4, 1998

7:00 a.m. - Noon	REGISTRATION & INFORMATION
7:00 - 8:00 a.m.	CONTINENTAL BREAKFAST
8:00 a.m. - Noon	**NEW CHALLENGES - NEW APPROACHES** Leland D. Smithson, *Iowa Department of Transportation*, presiding
8:00 a.m.	**By-Pass Oil Filters: Taking Your Fleet the Extra Mile** Donald S. Culpepper, *Gulf Coast Filters, Inc.*
8:40 a.m.	**Crane and Personnel Handling Equipment Inspections** Milton J. Luttrell III, *Aspen Aerials, Inc*.
9:20 a.m.	**Computerized, Cross Referenced Manuals and Parts List for Trucks and Off Road Equipment** John F. Schickler, *Service Professionals, Inc.*
10:00 - 10:30 a.m.	BREAK
10:30 a.m.	**Remanufacture: An Alternative to Rising Equipment Costs** Dominic J. Durinzi, Jr., *DEVAL Corp.*
11:10 a.m.	**Report on Regional Equipment Managers' Meetings** Dwight R. (Dick) Berkey, *Oregon Department of Transportation*
11:40 p.m.	**Research Problem Statements** Doug Nielsen
Noon - 1:00 p.m.	LUNCH
1:00 - 4:30 p.m.	**21ST CENTURY FLEET MANAGEMENT** Van M. Frazier, *Georgia Department of Transportation*, presiding
1:00 p.m.	**Fleet Management Information Systems Selection and Procurement** James Putnam, *Keane Associates*
1:40 p.m.	**Reengineering Fleet Management** Pam Nelson, *CCG Systems, Inc*.
2:20 p.m.	**Meeting The Outsource Challenge Competing for Equipment Maintenance Services** Randall G. Owen, *City of Charlotte, North Carolina*
3:00 - 3:30 p.m.	BREAK

3:30 p.m.	**The Jury Is In Turnkey Outsourcing Does Not Work** Kelly Walker, *Kelly Walker and Assoc.*
4:15 p.m.	**Research Statements** Doug Nielsen
6:00 - 10:00 p.m.	RECEPTION AND DINNER
	Archeological Discoveries in La Salle's 1680s Fort St. Louis Settlement and Shipwrecks in Matagorda Bay James E. Bruseth, Deputy State Historic Preservation Officer, and Archeology Division Director, *Texas Historical Commission*

Wednesday, August 5, 1998

7:00 a.m. - Noon	REGISTRATION & INFORMATION
7:00 - 8:00 a.m.	CONTINENTAL BREAKFAST
8:00 a.m. - 12:15 p.m.	**ALTERNATIVE FUELS** Richard W. Hunter, *Illinois Department of Transportation*, presiding
8:00 a.m.	**Energy Act Alternative Fuel Requirements and First Year Implementation** Kenneth Katz, *Alternative Fuel Transportation Program, U.S. Department of Energy*
8:40 a.m.	**Biodiesel Applications** Russ Teall, *NOPEC Corp.*
9:15 a.m.	**Natural Gas Vehicles: Availability, Cost, and Benefits** Richard Kolodziej, *Natural Gas Vehicle Coalition*
9:50 - 10:20 a.m.	BREAK
10:20 a.m.	**Propane Vehicles: Availability, Cost, and Benefits** Robert Meyers, *Propane Vehicle Council*
10:55 a.m.	**Electric Vehicle: A Practical Solution** Robert Kosak, *York Technical College*, *Rockhill, South Carolina*
11:30 a.m.	**Advancements in Diesel Technology for the Next Century** Pat Charbonneau, *Navistar International Corp.*
12:15 p.m.	**Future Meetings and Close Out** John M. Burns, Jr.
1:30 - 4:00 p.m.	**TOUR** Alamo Industries (manufacturer of mowing equipment) Seguin, Texas

Appendix B

12th Equipment Management Workshop: Participants List

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